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DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE FOR NEW SOURCES. BEET SUGAR PROCESSING SUBCATEGORY OF THE SUGAR PROCESSING POINT SOURCE CATEGORY

ENVIRONMENTAL PROTECTION AGENCY

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7. Author(s) Richard V. Watkins

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Environmental Protection Agency
Effluent Guidelines Division
Rm. 913, WSM-E 401 M. Street S.W.
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This document presents the findings of an extensive study of the beet sugar processing industry by the Environmental Protection Agency for the purposes of developing effluent limitations guidelines of performance and pretreatment standards for the industry to implement Sections 304(b) and 306 of the "Act."

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable" which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth a degree of effluent reduction which is achievable through the application of the best available demonstrated control technology processes, operating methods or other alternatives.

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DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

STANDARDS OF PERFORMANCE FOR NEW SOURCES

BEET SUGAR PROCESSING SUBCATEGORY OF THE SUGAR PROCESSING POINT SOURCE CATEGORY

Russell E. Train
Administrator

Robert L. Sansom
Assistant Administrator for Air and Water Programs

Allen Cywin
Director, Effluent Guidelines Division

Richard V. Watkins
Project Officer

January, 1974

Effluent Guidelines Division
Office of Air and Water Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This document presents the findings of an extensive study of the beet sugar processing industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines of performance and pretreatment standards for the industry to implement Sections 304(b) and 306 of the "Act".

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The standards of performance for new sources contained herein set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The regulations set forth the effluent limitations for discharge of process waste water pollutants to be met by July 1, 1977, by controlled discharge of barometric condenser water only or alternative attainment through discharge of composite beet sugar processing waste waters. The regulations for the remaining two levels of technology establish the requirement of no discharge of process waste water pollutants to navigable waters in all instances for new sources and as the best available technology economically achievable for existing sources except where plant size and soil filtration rate present practical economic restraints. Where plant size is less than 2090 kkg (2300 tons) per day of beets sliced, or soil filtration rate at the plant site is less than 0.159 cm (1/16 in) per day, effluent limitations for discharge of process waste water pollutants to be met by July 1, 1983, are given to be attained by controlled discharge of barometric condenser water only or alternative attainment through discharge of composite beet sugar processing waste waters.

Supportive data and rationale for development of the effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

In one sense, the beet sugar processing subcategory of the sugar processing point source category is a logical coherent industrial classification as evidenced by similarities in waste loads, waste water characteristics, and available waste treatment and control measures. Even though all plants, partially or fully, utilize land for disposal and/or control of beet sugar processing waste waters, individual conditions are acknowledged to affect application of a complete land- based technology. Factors such as climate, age, and size of plant may affect segmentation of the subcategory for purposes of effluent limitations guidelines development. The effluent limitation guidelines for July 1, 1983, reflect segmentation of the subcategory based on plant size, and soil filtration characteristics which are judged the most determinable, important, and influencing factors for segmentation. The segmentation is justified principally upon economic rather than technological considerations.

Presently, 11 of the 52 operating plants are achieving zero discharge of waste waters to navigable waters. A total of five beet sugar processing plants discharge flume and/or condenser water to municipal sewage systems. It is concluded that the remainder of the beet sugar processing subcategory of the sugar processing point source category can achieve the requirements as set forth herein by July 1, 1983. It is estimated that the capital costs of achieving such limitations and standards by all plants within the segment is less than $36 million. This figure assumes that no pollution control measures presently exist within the industry. In consideration of existing facilities estimates of total capital cost for achieving zero discharge to navigable waters range from $9 million to $16 million with availability of suitable land. With consideration of these plants without present availability of suitable land for controlled waste water disposal, cost might be expected to approximate $16 to $20 million. This would represent an increase in total capital invested in the industry under conditions of land availability of 1.0 to 1.7 percent. Overall cost increases for the production of sugar would vary from 0.2 percent to 2.2 percent depending on plant size, campaign length, soil conditions, and levels of control currently in place. The average cost increase for the industry would be approximately 0.3 percent.

A thorough analysis of the effects of pollution control requirements on the industry in terms of capital investment, marketing, employment, and plants likely to be adversely impacted economically is contained within the document entitled "Economic

Analysis of Proposed Effluent Guidelines, Beet Sugar Industry, U.S. Environmental Protection Agency, Office of Planning and Evaluation, Washington, D.C., August, 1973." That document sets forth the full economic impact of the established pollution control requirements.

SECTION II

RECOMMENDATIONS

Effluent limitation guidelines recommended to be met by July 1, 1977, for the beet sugar processing subcategory provide for a maximum discharge of process waste water pollutants to navigable waters as designated below. These effluent limitations are permitted to be met either by controlled discharge of process waste water derived from barometric condensing operations only or through discharge of composite process waste waters. This represents the degree of effluent reduction attainable by existing point sources through the application of the best practicable control technology currently available. No discharge of process waste water pollutants to navigable waters is recommended as the best available technology economically achievable, with exception for small plants or where unfavorable soil filtration rates are experienced. Where exceptions apply, effluent limitations are established for permitted controlled discharge of process waste water derived from barometric condensing operations only, or through discharge of composite process waste waters. No discharge of process waste water pollutants represents, for new sources, a standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The technologies for achieving the limitations and standards as set forth are based on maximum water reuse and recycling within the process to minimize net waste water production and controlled land disposal of excess waste water without discharge of such waste waters to navigable waters. Allowances for reaching the recommended effluent limitations through a controlled composite process waste water discharge permit appropriate use of demonstrated alternative pollutant reduction technologies. Disposal of waste water by controlled filtration on land or use for crop irrigation or other beneficial purposes is in conformance with no discharge of waste waters to navigable waters.

The following limitations establish the degree of effluent reduction attainable by the application of the best practicable control technology currently available:

The following limitations establish the quantity or quality of pollutants or pollutant properties, controlled by this regulation, which may be discharged by a point source subject to the provisions of this subpart after application of the best practicable control technology currently available; provided however, that a discharge by a point source may be made in accordance with the limitations set forth in either subparagraph (a) exclusively or subparagraph (b) exclusively below:

(a) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results from barometric condensing operations only.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD$_5$	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 32°C.	
(English units)	lb/1000 lb of product	
BOD$_5$	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 90°F.	

(b) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results, in whole or in part from barometric condensing operations and any other beet sugar processing operation.

Effluent Characteristic	Effluent Limitation	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD$_5$	3.3	2.2
TSS	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time.	
Temperature	Not to exceed 32°C.	

(English units)	lb/1000 lb of product	
BOD$_5$	3.3	2.2
TSS	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time.	
Temperature	Not to exceed 90°F.	

The following limitations establish the quantity or quality of pollutants or pollutant properties controlled by this regulation which may be discharged by a point source subject to the provisions of this subpart after application of the best available technology economically achievable.

(a) The following limitations establish the quantity or quality of pollutants or pollutant properties which may be discharged by a point source where the sugar beet processing capacity of the point source does not exceed 2090 kkg (2300 tons) per day of beets sliced and/or the soil filtration rate in the vicinity of the point source is less than or equal to 0.159 cm (1/16 in) per day; provided however, that a discharge by a point source may be made in accordance with the limitations set forth in either subparagraph (1) exclusively or subparagraph (2) exclusively below:

(1) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results from barometric condensing operations only.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD$_5$	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 32°C.	

(English units)	lb/1000 lb of product	
BOD5	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing pocess and in no event greater than 90°F.	

(2) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results in whole or in part from barometric condensing operations and any other beet sugar processing operation.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD5	2.0	1.3
TSS	2.0	1.3
pH	Within the range 6.0 to 9.0	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any time.	
Temperature	Not to exceed 32°C.	
(English units)	lb/1000 lb of product	
BOD5	2.0	1.3
TSS	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 MPN at any one time. (Not typically expressed in English units.)	
Temperature	Not to exceed 90°F.	

(b) The following limitations establish the quantity or quality of pollutants or pollutant properties controlled by this regulation which may be discharged by a point source in all instances not specified under the provisions of a) above: There shall be no discharge of process waste water pollutants to navigable waters.

SECTION III
INTRODUCTION

Purpose and Authority

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301 (b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including where practicable a standard permitting no discharge of waste water process pollutants to navigable waters.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the beet sugar processing subcategory of the sugar processing point source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing under Section 306 standards of performance applicable to new sources within the beet sugar processing subcategory of the sugar processing point source category, which was included in the list published January 16, 1973.

Summary of Methods Used for Development of the Effluent Limitations Guidelines and Standards of Performance

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The beet sugar processing subcategory was first studied for the purpose of determining whether separate limitations and standards are appropriate for different segments within the subcategory. This analysis included a determination of whether differences in raw material used, product produced, manufacturing process employed, as well as other factors which may exist, require the development of separate effluent limitations and standards for different segments. Raw waste characteristics for each subcategory were then identified and quantified. This included analyses of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in various plants; and (2) the constituents (including possibly thermal) of all waste waters including other constituents which result in taste, odor, and color in water. The constitutents of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within the subcategory was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants associated with effluent levels achievable by the application of each of the treatment and control technologies. The problems, limitations, and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise, and radiation were also identified and evaluated. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of these technologies.

The information, as outlined above, was then evaluated in order to determine the levels of technology constituting the "best practicable control technology currently available," "best available technology economically achievable," and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. They included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from its application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, required process changes, non-water quality environmental impact (including energy requirements), and other factors.

The data for identification and analysis were derived from a number of sources. These sources included EPA research information, published literature, a voluntary questionnaire survey of the industry conducted by the U.S. Beet Sugar Association, previous EPA technical guidance for beet sugar processing, qualified technical consultation, and on-site visits and interviews at better beet sugar processing plants throughout the United States. Each of these general sources provided information relating to the evaluation factors (cost, non-water quality impact effluent reduction benefits, etc.). All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this document.

General Description of the Beet Sugar Processing Subcategory

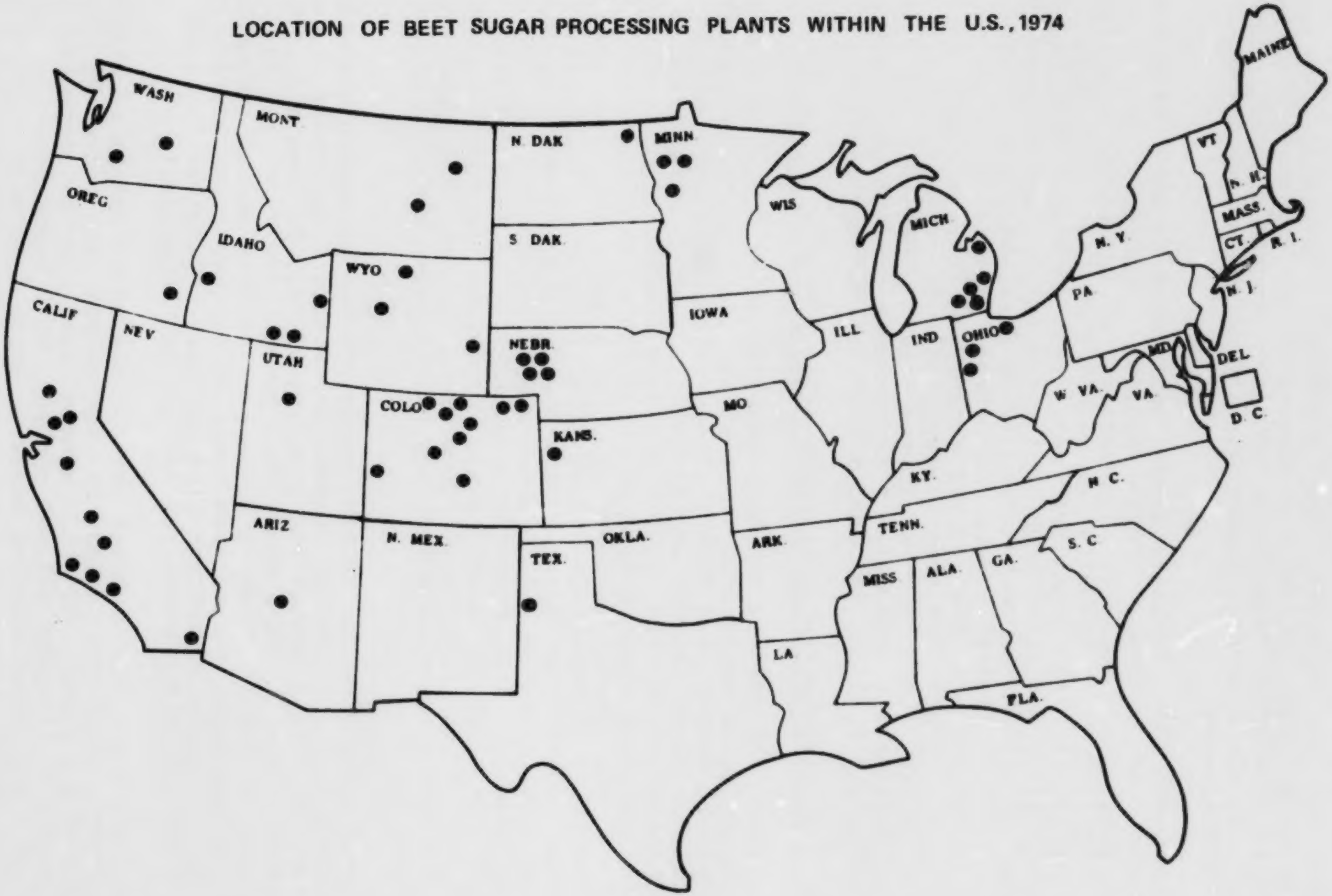
Although the culture of sugar beets is reported in early history, extraction of sugar from the beet was first begun on a commercial scale in Germany and France in the early nineteenth century. The earliest beet sugar enterprises in the United States were established in the 1830's in Pennsylvania, Massachussetts, and Michigan, but these plants and many others that followed failed in a few years because of low sugar yield from then known processing methods. In 1879, the Alvarado, California, beet sugar processing plant became the first successful operation in the U.S. because of higher sugar yields and production efficiency. The basic sugar extraction process for sugar beets has not changed since 1880. However, improved production equipment and increased processing rates, have progressively increased production efficiency particularly over the last twenty years.

There are a total of 52 beet sugar processing plants owned by 11 companies in the United States (see Figure I and Table I), with a combined daily processing capacity of 164,000 kkgs (181,000t) of beets. Capacity of these plants ranges from 1270 to 8200 kkgs (1400 to 9000t) of sugar beets per day with annual production of 3 million kkgs (3.3 million tons) of refined sugar (Tables II and III). A plant of average size handles approximately 3265 kkgs (3600t) of sliced beets per day during "campaign."

For a plant of average size, the waste waters if discharged without treatment would be equivalent in terms of organic polluting effect to the sewage load to be expected from a population of about 823,000 people. With consideration of in-place pollution control measures which have been constructed or installed by the beet sugar processing industry, the total potential pollution load from the average sized plant has been

Figure I

LOCATION OF BEET SUGAR PROCESSING PLANTS WITHIN THE U.S., 1974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N. MEX.
TEX.
OKLA.
ARK.
MISS
ALA.
GA.
LA
FLA.

TABLE I

Operating Beet Sugar Processing Plants in the United States (35)

Company	Plants
Amalgamated Sugar Company, Ogden, Utah	4
American Crystal Sugar Company, Fargo, North Dakota	6
Buckeye Sugar, Inc., Ottawa, Ohio	1
Holly Sugar Corp., Colorado Springs, Colorado	9
Michigan Sugar Company, Saginaw, Michigan	4
Monitor Sugar Company, Bay City, Michigan	1
The Great Western Sugar Company, Denver, Colorado	15
Northern Ohio Sugar Company, a wholly-owned subsidiary of The Great Western Sugar Company	2
Spreckels Sugar Division, Amstar Corporation San Francisco, California	5
Union Sugar Division, Consolidated Foods Corporation, San Francisco, California	1
Utah-Idaho Sugar Company, Salt Lake City, Utah	4
TOTAL	52

TABLE II

Consumption and Processing for the Beet Sugar Processing Industry

Production of Sugar Beets

Domestic production (1970)	25.9 million kkg	(28.6 million tons)
Percent sucrose of beets (1969)	12.59	
Sugar yield per harvested land area (1970)	5.21 kkg/ha	(2.33 ton/ac)
Number of beet sugar farms (1969)	18,424	
Domestic land area harvested (1969)	624,100 ha	(1,542,000 ac)
Planted land area harvested (1969)	35.7 ha	(88.2 ac)
Average land area harvested (1969)	33.9 ha	(82.5 ac)
Sugar beet yield per unit land area	41.5 kkg/ha	(18.5 ton/ac)

Raw Sugar Production (1969)

Total continental sugar production	4.17 million kkg	(4.6 million tons)
Cane sugar production	1.17 million kkg	(1.3 million tons)
Beet sugar production	3.00 million kkg	(3.3 million tons)
Other U.S. cane sugar production (Hawaii, Puerto Rico, and Virgin Islands)	1.45 million kkg	(1.6 million tons)
Total U.S. sugar production	5.62 million kkg	(6.2 million tons)
Total world sugar production	71.1 million kkg	(78.4 million tons)

Sugar Beets Processed (1969)

Total sliced	24.6 million kkg	(27.1 million tons)
Sucrose in cossettes, percent	14.36	

Domestic (U.S.) Refined Beet Sugar Production (1969)

Refined sugar per unit weight of beets received	113 kg/kkg	(226 lb/ton)
Refined sugar per unit weight of beets sliced	116 kg/kkg	(231 lb/ton)
Extraction rate based on weight of beets sliced	80.43 percent	

Sugar Consumption (1969) - Raw Value

Total U.S. sugar consumption	9.61 million kkg	(10.6 million tons)
Per capita U.S. consumption (refined value)	44.7 kg	(98.6 lb)

Miscellaneous Information (based on weight of beets sliced)

Typical sugar content of beets	15%
Typical sugar recovery, non-Steffen plant	70 - 85%
Typical sugar recovery, Steffen plant	80 - 95%
Typical dried pulp production	4.5%
Typical molasses production, non-Steffen plant	4.5%

TABLE III

Present and Projected Processing Capacity of Beet Sugar Processing Plants by States

State	Number of Plants	Rated 1973 Capacity Wt. of Beets Sliced/Day, kkg	(tons)	Projected Capacity 1980 Wt. of Beets Sliced/Day kkg	(ton)
California	10	28,400	(1,300)	36,300	(40,000)
Colorado	10	24,500	(27,000)	26,600	(29,300)
Michigan	5	10,200	(11,250)	10,700	(11,800)
Idaho	4	22,600	(24,920)	22,600	(24,950)
Minnesota	3	10,400	(11,500)	13,500	(14,750)
Nebraska	4	9,000	(9,900)	9,100	(10,000)
Montana	2	7,000	(7,700)	10,400	(11,450)
Ohio	3	6,000	(6,650)	5,000	(5,130)
Utah	1	2,200	(2,430)	5,800	(6,350)
Wyoming	3	6,500	(7,200)	6,800	(7,500)
Washington	2	11,200	(12,325)	12,500	(13,800)
Arizona	1	3,800	(4,200)	3,800	(4,200)
Kansas	1	2,900	(3,200)	3,300	(3,600)
North Dakota	1	4,700	(5,200)	4,500	(5,000)
Oregon	1	6,000	(6,600)	6,500	(7,200)
Texas	1	6,000	(6,600)	5,900	(6,500)
	52	161,400	(188,400)	183,300	(202,100)

substantially reduced to approximate an equivalent pollution load of a population of 15,000 to 110,000. Pollution load is estimated in terms of present waste water discharged to surface waters as BOD_5.

Within the U.S., beet sugar processing plants are located from the warmer areas of Southern California and Arizona to the cool temperature regions of Montana, Minnesota, and North Dakota. Sugar beets are also processed in modern plants in Canada, Great Britain, Western Europe, Poland, the Soviet Union, and other countries. There are some 800 beet sugar plants in Europe and in North America and all use the same basic technology for processing. About 15% of U.S. beet sugar processing is carried out individually by each of the states of California, Idaho and Colorado. Minnesota, Michigan and Washington each process about six percent while the remaining 37 percent of the sugar beets are about equally distributed among eleven other states.

Processing and Refining Operations

General

The raw materials entering beet sugar processing operations are sugar beets, limestone, small quantities of sulfur, fuel, and water. The products are refined sugar, dried beet pulp, and molasses. The average raw material requirements and end products produced per unit weight of clean beets processed are given below for non-Steffen and Steffen processes (30).

NON-STEFFEN PLANTS

Raw Material or End-Product	Per Unit Weight of Sliced Beets
Limestone	40.0 kg/kkg (80 lb/ton)
Fuel, gas or coal	6.9×10^5 kg cal/kkg (2.5×10^6 BTU/ton)
Avg. water intake	9150 l/kkg (2200 gal/ton)
Dry Beet pulp	50.1 kg/kkg (100 lb/ton)
Sugar product	130 kg/kkg (260 lb/ton)
Molasses produced	50.0 kg/kkg (100 lb/ton)
Avg. waste water flow	8780 1/kkg (2100 gal/ton)

STEFFEN PLANTS

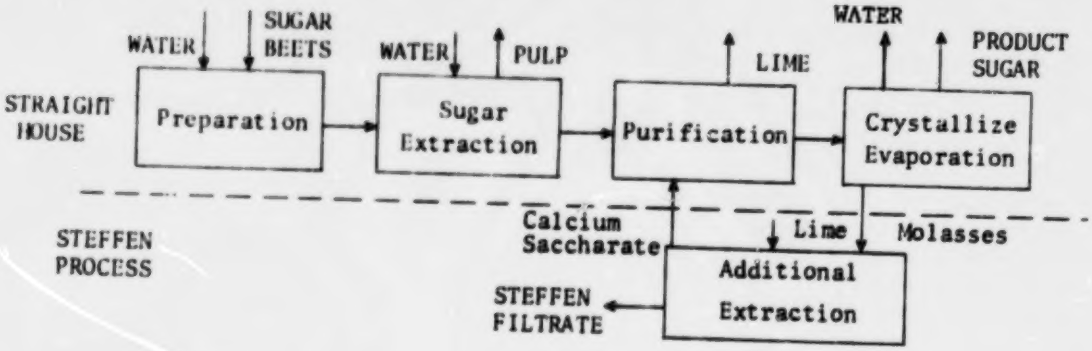
Molasses worked	50.1 kg/kkg (100 lb/ton)
Additional limestone	20.0 kg/kkg (40 lb/ton)
Additional sugar produced	15.0 kg/kkg (30 lb/ton)
Steffen filtrate	376 1/kkg (90 gal/ton)

The various unit operations required for converting sugar beets into refined sugar are many and complex, but they are essentially the same in all plants in this country. The basic processes consist of slicing, diffusion, juice purification, evaporation, crystallization, and recovery of sugar.

The sugar beet harvesting, piling and processing periods vary in different sections of the country. The processing season or "campaign" extends from early September to late February or early March in Ohio, Michigan, North Dakota, Minnesota, and the Rocky Mountain Region. However, the length of the processing season is variable and sometimes intermittent, being highly dependent upon climatic conditions. In the warmer areas, the beet processing season may extend from April to late December. The sugar beet processing campaign is a seasonal activity operating on a 24-hour a day basis, 7 days a week during the "campaign." From 40 to more than 400 seasonal workers are employed at a single plant. The smaller work force of 40 persons is representative of the inter-campaign period.

Incoming sugar beets contain between 10 and 16 percent sugar, about 5 percent non-soluble matter (called "marc") and water. The initial process for the extraction of purified sugar and the formation of byproduct molasses (the "straight house") is identical throughout the industry. Some plants also have an additional operation, the "Steffen process," for the extraction of additional sugar from molasses. Whether a plant is a "straight house" or a "Steffen process" operation, the end product of the beet sugar processing plant is refined sugar. In the straight house or non-Steffen process the byproduct molasses containing approximately 85 percent solids and 15 percent water results. The total molasses produced accounts for approximately 4.5 percent of the weight of beets sliced. Sugar extraction efficiency in the straight house or non-Steffen process is approximately 75 percent. The Steffens process operation enables the plant to extract additional sugar from the molasses produced in a straight house operation and, with this addition, the production may be 85 percent efficient in total extraction of the sugar from raw beets. Of the 52 beet sugar processing plants in the U.S. at present, 20 utilize the Steffen process.

In recent years, there has been a trend toward a lower "purity" beet, i.e. lower sugar content. The lower purity of beets is attributed to their harvest prior to maturity in order to maintain uniform processing rates and therefore a longer processing season (e.g. California), nitrogen use during the growing season, and pile storage deterioration during longer campaigns (in northern climates). Higher nitrogen content of soils through wide spread fertilizer use, and increased emphasis on sugar beet breeding for disease resistence also may be factors in reduced beet purity. With lower purity of beets, the sugar extraction efficiency in a straight house operation decreases substantially, approaching 70 percent, with the sugar which is not extracted being retained in the byproduct molasses.


WATER
SUGAR BEETS
WATER
PULP
LIME
WATER
PRODUCT SUGAR
STRAIGHT HOUSE
Preparation
Sugar Extraction
Purification
Crystallize Evaporation
STEFFEN PROCESS
Calcium Saccharate
Lime
Molasses
Additional Extraction
STEFFEN FILTRATE

Production Classification

The U. S. Bureau of the Census of Manufacturers classifies the beet sugar processing subcategory of the sugar processing point source category as Standard Industrial Classification (SIC) Group Code Number 2063 under the more general category of Sugar and Confectionery Products, Food and Kindred Products (Major Group 10). The four-digit classification code (2063) comprises industrial establishments primarily engaged in manufacturing sugar and sugar products from sugar beets. A detailed list of product codes within the broad beet sugar processing industry classification code (2063) is included in Table IV.

Regulations and Future Growth

Federal Sugar Act

Until the late 1940's the economic stability of both the beet sugar and the cane sugar processing industry fluctuated widely. Tariff reductions on imported sugar seriously depressed the domestic sugar economy throughout its growth. The sugar industry is now protected and operates on a quota system established by the Federal Sugar Act of 1948 which was amended in July, 1962. Quotas are established on both domestic and foreign sugar. Under the Federal Sugar Act, the price of sugar is controlled by the Secretary of Agriculture. Annually the total national sugar requirement is projected and sales quotas to domestic producers are adjusted accordingly.

TABLE IV

Product Classification by SIC Code for the Beet Sugar Processing Industry(3

SIC Product Code			Product
20630			Refined beet sugar and byproducts
			Granulated beet sugar:
		20630-09	Shipped in individual services (small packets)
		20630-11	Shipped in consumer units (cartons & sacks of 25 lbs. or less)
		20630-13	Shipped in commercial units (bags & other containers more than 25 lbs.)
		20630-15	Shipped in bulk (railcars, trucks, or bins)
	20630-21		Cube and tablet sugar:
			Confectioners powdered sugar:
		20630-31	Shipped in consumer units (containers of 10 lbs. or less)
		20630-35	Shipped in commercial units (containers of more than 10 lbs.)
			Liquid sugar or sugar syrup:
		20630-51	Sucrose type
		20630-55	Inert and partially inert type
			Other beet sugar factory products and byproducts
			Whole or straight house molasses:
		20630-71	Shipped for desugarization
		20630-79	Shipped for other uses
	20630-81		Discard molasses
	20630-83		Molasses beet pulp
	20630-85		Dried beet pulp, plain
	20630-87		Wet beet pulp (estimated dry weight basis)

Anticipated Industry Growth

Under the present Federal Sugar Act, the beet sugar processing industry is permitted to increase its production at a rate of 3 percent annually. The growth and development of beet production areas and processing facilities may be in new areas as well as in present beet-growing areas. Some companies anticipate very large increases at certain plants and little or no growth at others. Additional beet sugar processing plants are presently being considered for construction in the United States. One such plant is being considered at Renville, Minnesota, to replace a former plant at Chaska, Minnesota, which was closed in 1970. This plant reportedly may employ an ion exchange process for extracting sugar from molasses rather than the conventional Steffen process. A plant is also proposed at Wahpeton, North Dakota. Another plant at Hillsboro, North Dakota is under construction with completion scheduled for 1974.

Large population growth, urban encroachment due to land development, and increased land values are likely to result in decreased growth of the beet sugar processing industry in Colorado. Industry experts predict that the areas of future growth of the beet sugar processing industry will be the Red River of the North (Minnesota and North Dakota), and the Columbia River Basin. Expansion of the industry may be expected in Kansas and Nebraska because of proximity to sugar beet growing areas and land availability for future beet sugar processing plant sites with opportunity for land disposal of waste waters.

SECTION IV

INDUSTRY CATEGORIZATION

Profile of Production Processes

Beginning with arrival of sugar beets at a given plant to the production of refined sugar, the production processes, beet handling methods, and associated plant management are all considered part of the total plant system. Detailed narrative descriptions of processes and methods associated with beet sugar processing are given below. The description serves as an introduction to the rationale for segmentation the beet sugar processing subcategory of the sugar processing point source category.

Delivery and Storage of Beets

Beets are delivered to the plant by trucks or railroad cars and stored in large piles or dumped directly into flumes for transport into the processing plant. Beets must generally be stored for periods ranging from 20 to 100 days or more, since the processing period takes considerably longer than the harvest. In areas benefited by low ambient temperatures, beets can be stored in large piles until processing begins. However, during the storage period, considerable deterioration of beets may occur. Loss of recoverable sugar from beets through inversion in storage occurs even under the best of storage conditions. Therefore, great effort is made to reduce the time in storage by maintaining maximum slicing rates in the processing plants to the possible detriment of sugar extraction efficiency. Storage of beets in piles is not practiced in California and other areas where the prevailing warmer winter temperatures would encourage rapid beet deterioration. The harvest is carefully regulated in these regions so that beets may be processed soon after removal from the field. If harvesting is interrupted by winter rains, the plants are closed until harvesting can resume.

Transporting, Washing, Slicing and Weighing

Sugar beets are transported from the delivery point or storage piles to the process by water flumes. The beet transport flumes are provided with rock catchers which trap and remove stones and other heavy foreign material from flume flow. Trash catchers remove light material including weeds and loose beet tops. The sugar beets are lifted from the flume to a beet washer by a beet wheel and are discharged from the washer to a roller conveyor where they receive a final washing by high pressure sprays of clean water. Water from the beet washer and sprays is discharged into the flume system. The washed beets are sliced into thin ribbon-like strips called "cossettes," and fed into a continuous diffuser. A scale is usually installed in a section of the belt feeding the diffuser to weigh the sliced beets entering this portion of the process.

Sugar Extraction by Diffusers

The diffuser extracts sugar and other soluble substances from the cossettes under a counter-current flow of water. The liquor or "raw juice" containing the sugar and other soluble substances is pumped to purification stations. This raw juice contains between 10 and 15 percent sugar.

Disposal of Exhausted Cossettes

The exhausted beet pulp or cossettes are conveyed to pulp presses where the water content is reduced from about 95 percent to approximately 80 percent before the pulp is fed into a pulp drier where the pressed pulp is further dried to a moisture content of 5 to 10 percent. The pulp press water is usually returned to the diffuser as part of the diffuser supply. The dried pulp is utilized as a base for livestock feed. Only one plant in the industry now stores wet beet pulp in a silo. This silo is scheduled for replacement with a pulp drier by October, 1973.

Carbonation of Raw Juice, Clarification, Concentration, and Separation

The raw juice from the diffuser containing most of the sugar from the beets as well as soluble and colloidal impurities is pumped to the first carbonation station. Lime (calcium oxide), slaked lime, or calcium saccharate (from the Steffen process) is added to the raw juice and the juice is then saturated with carbon dioxide gas to precipitate calcium carbonate. The calcium carbonate sludge thus formed carries with it suspended impurities in the juice and is separated from the mixture by vacuum filters. The "thin juice," after further treatment with carbon dioxide, filtration, and sulfur dioxide to reduce the pH to about 8, is concentrated in multiple-effect evaporators to a "thick juice" (65 percent solids) and then boiled in a vacuum pan crystallizer to obtain the crystallized sugar. The sugar is separated by centrifugation from the adhering syrup and dried. The remaining syrup is further concentrated to yield additional crystalline sugar and molasses. The molasses may be added to the exhausted beet pulp and sold for animal feed or may be further desugarized by the Steffen process.

The Steffen Process

In this process the molasses produced from the straight house operation is diluted, cooled and treated with calcium oxide to precipitate the sugar as a saccharate. The calcium saccharate, after separation by filtration from the remaining solution of impurities (Steffen filtrate), is returned to the first carbonation station in the straight house process. The Steffen filtrate may be discharged as a waste, or after precipitation and removal of calcium carbonate by addition of carbon dioxide (carbonation), be evaporated to a thick liquor called concentrated Steffen filtrate. This filtrate may be dried in combination with beet pulp or used as a source for the production of such byproducts as monosodium glutamate and potash fertilizer salts.

Categorization of the Beet Sugar Processing Industry

The beet sugar processing subcategory of the sugar processing point source category is defined as the production of refined sugar utilizing sugar beets as a raw material.

Factors Considered

With respect to identifying any relevant, discrete segments for the beet sugar processing subcategory of the sugar processing point source category the following factors or elements were considered in determining whether the industry subcategory should be subdivided into segments for the purpose of the application of effluent limitations guidelines and standards of performance:

1. Waste water constituents
2. Treatability of wastes
3. Raw materials
4. Products produced
5. Production processes and methods
6. Size and age of production facilities
7. Land availability, climate, and soil conditions

After considering all these factors it is concluded that the beet sugar processing subcategory of the sugar processing point source category comprises a single and coherent industry subcategory. Accordingly, categorization is based on the entire industry, encompassing all plants, processes, wastes, and descriptive elements in a single subcategory as defined above. Plant size and soil factors are determined to be of significant economic importance in achievement of pollution control levels, and have been appropriately considered in segmentation of the subcategory for purposes of the July 1, 1983, effluent limitation guidelines.

Raw Waste Water Constituents and Treatability

The nature and characteristics of raw waste components released for treatment or control from any beet sugar processing plant are similar. Moreover, all effluents respond to, and are treated by, the same or similar waste treatment systems. As with other factors considered, wastes and treatment systems show some variations (e.g., increases in total waste loads as lime mud slurry from Steffen plants). However, the variations are not sufficient in magnitude to warrant segmenting the subcategory on this basis. Typical waste water constituents, waste loads, and flow data for the beet sugar processing subcategory of the sugar processing point source category are included in Table VI.

The difference in waste load by comparison of a Steffen to a non-Steffen beet sugar processing plant of comparable capacity results from additional lime use in clarification of sugar solutions, the generation of Steffen filtrate, and the possibility of additional organic entrainment of barometric condenser water through the additional concentration in the Steffen process. In practical terms, these additional waste sources present little impact on the total plant pollutional waste load volumes and effects under present waste disposal practices.. A Steffen house operation may contribute a lime mud slurry volume of 680 l and BOD_5 of 9.5 kg/kkg (180 gal and 19 lb/ton) of beets sliced in comparison to 340 l and 3.2 kg/kkg (90 gal and 6.5 lb/ton) of beets sliced for a non-Steffen process. Under present plant practices, the relatively small lime slurry volume generated at beet sugar processing plants (Steffen or non-Steffen) is disposed of on land without discharge to navigable waters. Steffen filtrate, resulting from extraction of sugar from molasses in the Steffen process, is universally concentrated for byproduct recovery or disposed of on land without discharge to navigable waters. The Steffen filtrate is a small waste volume of 510 l/kkg (120 gal/ton) of beets sliced of high pollutional load of 5.2 kg BOD_5/kkg (10.4 lbs/ton) of beets sliced. Additional sugar entrainment in the evaporation and crystallization process can result in an increase of 0.05 kg BOD_5/kkg (0.1 lb/ton) of beets sliced in a Steffen process as compared to 0.25 kg BOD_5/kkg (0.5 lbs/ton) of beets sliced commonly expected for a non-Steffen process. The additional waste load is not significant as compared to the total plant waste load and may be reduced or eliminated by the identical technology judged applicable to a non-Steffen process.

Raw Materials and Final Products

Raw materials (e.g., sugar beets, water, limestone, and fuel) and final products do not provide a basis for segmenting the industry, as the essential characteristics of these materials are consistent throughout the industry. Unimportant variations in the composition of these materials may exist as exemplified by sugar beets themselves. The beets will vary slightly in quality and characteristics primarily in terms of the sugar content and amount of associated incoming "tare" and debris. These variations are not unique, are experienced throughout the industry, and are influenced by cultural practices, care in harvesting of the beets, climatic conditions, handling procedures, and beet storage practices.

Water use is determined by the needs of the individual plant, and under existing practices is primarily influenced by the temperature and quality of available water supply sources and the degree of inplant water reuse. Water use by beet sugar processing plants varies markedly due to these variables.

The quality of product (refined sugar) is uniform throughout the industry. Differences arise in the various uses for which the final product is made or the method of packaging for the buyer. The latter factors are not environmental quality related in their relationship to beet sugar processing. Lime used in the process for precipitation of impurities and pH control is disposed of essentially by the same technique throughout the industry.

Energy requirements in a beet sugar processing plant are fairly uniform at 1.2 kw of electrical energy per kkg (1.3 hp/t) of beets sliced per day. Small variations can be attributed to ancillary activities such as pollution abatement equipment. Sugar, molasses, and beet pulp are the three major products produced in all plants and industry-wide product quality control effectively eliminates any significant differences in unit quantity of production or product characteristics.

Production Processes and Methods

As discussed in the previous section, there is little to differentiate in the essential operations conducted for beet sugar processing at all plants. Improved sugar recovery processes (e.g., Steffen Process) lead to enhanced inprocess recycle efficiencies but show no material effect upon overall production methods. Other unit processes such as slicing, extraction, pulp pressing, and carbonation for juice clarification are uniform in all plants. The quality of the juice resulting from the diffusion process may vary with beet storage and growing conditions.

Some plants within the beet sugar processing industry operate what is referred to as an "extended use" campaign. In such operations, the "thick juice" after purification and concentration is stored in part for processing through the sugar end of the plant during the intercampaign. The effect of such operations on raw waste loads from the plant is to extend the period of waste water generation over the thick juice processing period. The total waste load remains the same. However, the waste generated as a problem source in the processing of beets to thick juice is of primary consideration (flume, condenser, and lime mud wastes). The processing of thick juice in the intercampaign in the sugar end of the process adds only a small waste load attributed primarily to contaminants in barometric condenser waters of the crystallization tank without adequate entrainment control devices.

In consideration of the relatively small waste load attributed only to barometric condenser water resulting from the extended use campaign, such procedures are not justification for segmentation of the beet sugar processing subcategory. Waste disposal facilities designed and operated to adequately dispose of waste waters resulting during the beet processing season serve adequately during the "extended use" campaign operations, since these two activities are not conducted concurrently.

Land Availability, Climate and Soil Conditions

Land availability and climatic and soil conditions are principal factors that must be considered in the handling and disposal of beet sugar processing waste waters.

Climate, soil conditions, and land availability vary in various regions of the country and at individual plant sites. Very tight soil in terms of percolation characteristics exists in some geographical regions (e.g., glacial till soils of Michigan, Ohio, and the Red River of the North in North Dakota and Minnesota) which necessitates greater reliance upon evaporation and increased land requirements as a mechanism for obtaining no discharge of process waste water pollutants to navigable waters. Land availability is particularly an important factor where because of climate and soil conditions increased reliance on pond surface evaporation is required. Based on mass water balance relationships developed in this document, land for no discharge of process waste water pollutants to navigable waters with extensive recycling and controlled land disposal of waste waters (0.635 cm or 1/4 in per day allowable filtration rate) requirements are approximately 50.6 ha (100 ac) for the average-sized plant. Greater land requirements may result under adverse land disposal conditions. Present practice in much of the industry is the construction and use of much larger land disposal areas for waste disposal than actually required for this purpose. Necessary land is generally available under the prevailing climate and soil conditions throughout the industry for controlled land disposal of waste waters. Controlled land disposal of waste water by reliance on maximum allowable soil filtration rates alone effectively eliminates variable climatic factors such as rainfall and evaporation as concerns in the recommended land based waste water disposal and control technology. With the exception of the Michigan-Ohio area (where lake evaporation nearly compensates for annual rainfall) additional waste water losses may be attributable to net evaporation as well as filtration. Factors related to land availability and soil characteristics need to be fully considered in application of effluent guidelines and limitations for a land based waste water control technology. Adverse soil filtration rates such as experienced in the Michigan-Ohio area substantially increase land area requirements for land disposal of waste waters, thus affecting the technological and economic feasibility of land disposal under these circumstances. Inadequate soil filtration is judged to present an economic justification for segmentation of the subcategory in development of effluent limitations guidelines applicable to July 1, 1983.

Size and Age of Production Facilities

As can be determined from Table V, over seventy percent of both the number of plants and production capacity are in the range of 1800-4700 kkgs (2000 - 5200 tons) a day; with the balance of the plants characterized by the same order of magnitude. Age of

TABLE V

SIZE DISTRIBUTION OF BEET SUGAR PROCESSING PLANTS IN THE UNITED STATES, DAILY SLICING CAPACITIES

Slicing Capacity in kkg/day (ton/day)	Number of Plants
1270 (1400) or less	1
1450 - 1810 (1600 - 2000)	7
2200 - 2180 (2001 - 2400)	11
2181 - 2630 (2401 - 2900)	4
2631 - 3080 (2901 - 3400)	7
3081 - 3450 (3401 - 3800)	6
3451 - 3990 (3801 - 4400)	6
3991 - 4710 (4401 - 5200)	3

5890 - 6350 (6500 - 7000)	5

6351 - 8610 (7000 - 9500)	1

More than 8610 (9500)	1
TOTAL	52

equipment and facilities proves unimportant because the industry has been continually modernizing operations to enhance production efficiency. Size of plant bears a general relationship to land available -- the smaller plants being generally located in more urbanized areas with climatic and soil conditions less favorable than other areas for controlled land disposal. The relationship is only general in context; there are notable exceptions to the generalization. Of great importance is the increased economic impact on the smaller plant as compared to larger plant operations. This economic factor serves as the primary justification of segmentation of the subcategory in development of effluent limitations guidelines applicable to July 1, 1983. Raw waste load characteristics and quantities for various waste water components are reliably related to unit production rates, thereby eliminating size as a possible factor in generation of disproportionate waste loads by capacity of plant.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

Specific Water Uses

Water is commonly used in a beet sugar processing plant for six principal purposes: Transporting (fluming) of beets to the processing operation, washing beets, processing (extraction of sugar from the beets), transporting beet pulp and lime mud cake waste, condensing vapors from evaporators and crystallization pans, and cooling.

The quantity of fresh water intake to plants ranges between 1,250 and 25,000 l/kkg (200 and 6,000 gal/ton) of beets sliced. Fresh water use is highly contingent upon in-plant water conservation practices and reuse techniques. Average water use in the industry approximates 9200 l/kkg (2200 gal/ton) of beets processed. Total water used, including reused water, varies much less and totals approximately 20,900 l/kkg (5000 gal/ton) of beets sliced. Most of the water used in beet sugar processing plants is employed for condensing vapors from evaporators, and for the conveying and washing of beets (see Table VI). Since many process uses do not require water of high purity, considerable recirculation is possible without extensive treatment. The nature and amounts of these water reuses as influenced by in-plant controls and operational practices have a substantial effect on resulting waste water quantities and characteristics. Reduction in water use with minimum waste water volumes promises fewer difficulties in waste handling and disposal, and greater economy of treatment. Water uses for various operations in a beet sugar processing plant are further described below.

Flume or Beet Transport Water

As previously mentioned, transport of beets from piles, trucks, or railroad cars into the plant is invariably accomplished by means of water flowing in a narrow channel (flume) which provides for handling and conveyance of the beets and removal of much adhered soil. Beets are lifted from the flume to a washer and subjected to a final wash by sprays. The combined flume, wash, and spray water constitutes the largest single use of water in a beet sugar processing plant, and ranges between 5,000 and 17,000 l/kkg (1,200 and 4,000 gal/ton) of beets, averaging about 11,000 l/kkg (2,600 gal/ton.) In most plants, flume water is recycled after separation of much of the suspended soil. Flume water generally accounts for approximately 50 percent of the total plant water use. Water used for fluming in many plants is drawn in part from barometric condenser seal tanks. In some plants, fresh water is used, either alone or as a supplement to condenser water. The use of warm condenser seal tank water for fluming is

TABLE VI
REPRESENTATIVE WASTEWATER CHARACTERISTICS AND TOTAL FLOW DATA FOR A TYPICAL BEET SUGAR PROCESSING PLANT (*)

Waste Source	Flow l/kkg of beets sliced (gal/ton)	BOD_5 (mg/l)	BOD_5 kg/kkg of beets sliced (lb/ton)	Suspended Solids (mg/l)	Suspended Solids kg/kkg of beets sliced (lb/ton)
Flume Water	10,842 (2600)	210	2.25 (4.5)	800-4,300	8.5-41.5 (17-93)
Process Water					
Screen (Pulp Transport) Water	1668 (400)	910	1.50 (3.0)	1,020	1.7 (3.4)
Press Water	751 (180)	1,700	1.30 (2.6)	420	0.3 (0.6)
Silo Water	876 (210)	7,000	6.15 (12.3)	270	0.25 (0.5)
Lime Mud Slurry**	375 (90)	8,600	3.25 (6.5)	120,000	45 (90)
Condenser Water	8340 (2000)	40	0.35 (0.7)	-	
Steffen Filtrate	500 (120)	10,500	5.20 (10.4)	100-700	0.05-0.35 (0.1-0.7)
Totals	23,352 (5600)		20.0 (40.0)		55.8-94.1 (111.6-188.2)

(*) All values are based upon no recirculation or treatment of waste waters (24,25,26,48).

(**) Relates to non-Steffen or straight house process.

often found to be advantageous in cold climates to thaw frozen incoming beets.

Process Water

Process water is associated with the operations of extraction of sugar from the beet. About 920 liters/kkg (220 gal of makeup water/ton) of beets are used for this purpose. Available data indicate considerably more water use in some instances, but these instances apparently include some pulp transport water. Nearly all plants practice complete process reuse of pulp transport water and return pulp press water to the diffuser. Dry pulp handling with elimination of pulp transport water is a common practice. The weight of raw juice drawn from the diffuser is approximately 125 percent of the weight of sliced beets entering the diffuser. This ratio, called "draft," varies between 100 and 150 percent. The discharged pulp contains about 95 percent moisture when it leaves the diffuser and is reduced to about 80 percent moisture by pressing. Any necessary makeup water in the diffuser may be obtained from fresh water supplies, condensate water from the heaters, barometric condenser water, or a combination of these sources. Barometric condenser water is not the most desirable source of makeup water since it contains undesirable dissolved solids after cooling and reuse. Heater condensate is preferred and generally considered to be far more suitable for use in the diffuser.

Lime Mud System

Raw juice impurities contained in the calcium carbonate sludge in the clarification process are removed from clarification tanks and conveyed to a rotary vacuum filter for dewatering. The resultant lime mud cake contains approximately 50 percent solids which are normally slurried with fresh water or condenser water to about 40 percent solids and pumped to a lime mud pond. A high quality water for slurrying is not required. Lime use within a beet sugar processing plant generally amounts to approximately 2.4 to 4.0 percent by weight of the beets processed. Water for slurrying and pumping lime mud to land disposal facilities is not normally metered but may be estimated on the basis of the lime dosage used. At one plant, water use for slurrying is estimated at 170 l/min (45 gal/min) or 40 l/kkg (10 gal/ton) of beets processed on the basis of 22.6 percent calcium content of the lime mud cake and 12.0 percent in the lime mud slurry. The quantities actually used vary from less than 41.7 l/kkg (10 gal/ton) of beets processed to more than 417 l/kkg (100 gal/ton). Many plants use between 83.5 and 251 l/kkg (20 and 60 gal/ton) of beets sliced averaging about 208 l/kkg (50 gal/ton). Recent trends are toward reduced use of water in the lime mud slurry. The lime mud slurry, though relatively small in volume, is very high in BOD5 and suspended solids. With careful control, water use for lime mud slurrying can be limited to less than 41.7 l/kkg (10 gal/ton) of beets processed for a straight-house operation. Semi-dry lime mud handling techniques as practiced at some plants are effective in limiting water use for lime mud slurrying purposes. Because of additional sugar extraction from straight house molasses in the Steffen operation through additional lime precipitation, the Steffen process results in increased lime mud volumes for disposal. Reduced water volume techniques for handling lime mud from straight house operations are equally applicable to lime mud produced from the Steffen process.

Barometric Condenser Water

Barometric condensers are commonly employed in the operation of pan evaporators and crystallizers in the beet sugar processing industry. Water in large quantities is required for this purpose. The quality of the water is not of critical importance, but since the most readily available source of cold water is generally the fresh water from wells or streams it is usually relatively pure. In 27 of the 52 plants in the United States condenser water is cooled by some type of cooling device and recycled in varying degrees for reuse in the plant. In 35 of the beet sugar processing plants within the United States, spent condenser water frequently is reused, principally for fluming beets. The amount of barometric condenser water used varies between 5400 and 18,800 l/kkg (1300 and 4500 gal/ton) of beets processed. The average use is approximately 8250 l/kkg (2,000 gal/ton) of beets sliced.

Steffen Dilution Water (Steffen Process Only)

The Steffen process is employed by 20 beet sugar processing plants. In this process, molasses containing about 50 percent sucrose is diluted with cold fresh water to produce a "solution-for-cooler" containing 5 to 6 percent sucrose.

In the South Platte River Basin Steffen house process plants account for higher water use than non-Steffen plants because of lower temperature and greater cooling water requirements in the processing of the molasses solution. The use of heat exchangers in these plants such as presently employed in other regions (e.g., California) for cooling the molasses solution could reduce this high fresh water use for cooling and support the economic use of cooling towers.

Miscellaneous Water Uses

Condensate water from steam or vapors in heating and evaporation of raw juice produces high-quality water ranging between 150 and 200 percent of the weight of beets sliced. The purest of these condensates is collected and used as boiler feed. Normally, no other water is used for this purpose. Condensate waters are used for many other purposes: Diffuser supply (in part); press wash, i.e., washing of lime mud cake precipitate; centrifugal wash; and house hot water (cleaning evaporators, floors, etc.). Miscellaneous water uses vary widely among plants with housekeeping practices. Floor drainage water may vary between

38,000 and 1,500,000 l (10,000 and 400,000 gal) per day for plants ranging from 1360 to 6000 kkgs (1500 to 6600t) of beets sliced a day, respectively. The floor drainage waste may typically contain approximately 2400 mg/l BOD_5 and 3000 mg/l sugar as sucrose. Gas washer water also varies considerably from 30,300 to 1,326,000 l (8,000 to 350,000 gal) a day at plants in the industry.

Factors Affecting the Quantity and Quality of Waste Waters

Even though all beet sugar processing plants in this country and abroad use essentially the same basic processes for production of refined sugar, facilities for handling waste waters vary markedly from plant to plant.

Two relatively recent and important equipment changes have been made in United States beet sugar processing plants which have affected water use and corresponding quantities of wastes. These are the installation of continuous diffusers and widespread use of pulp driers. Replacement of the Roberts (cell-type) diffuser with the continuous diffuser was completed in 1967 for all plants. The new diffuser showed important reductions in water required in the process by permitting reuse of pulp press water. With the cell-type diffuser, pulp screen water and pulp press water were discharged as waste. The first pulp drier was installed in an American plant over 50 years ago, and by October, 1973, it is anticipated that all plants will be equipped with modern driers. One plant uses a silo for disposal of wet exhausted beet pulp.

Concentration of the Steffen waste produced at Steffen process plants by evaporation is also commonly practiced. Before evaporation of Steffen waste was generally practiced, the BOD_5 discharge was 5.0 kg/kkg (10 lbs/ton) of beets from this source. Concentration of Steffen wastes now permits substantial reductions in waste volume which permits easier handling, disposal and by-product use.

The amount of water reuse varies greatly among beet sugar processing plants. At one plant in 1968 the total water use, including reuse, exceeded the fresh water intake by only 24 percent; while at another plant the total use exceeded intake water by 1,300 percent as water shortages engendered maximum conservation. At most plants fresh water intake constitutes one-third to one-half of the total use; although fresh water constituted less than 20 percent of the total water use in six plants in 1968.

The greatest reduction in fresh water use within the past two decades has been accomplished by the recirculation of flume water and by the reuse, after cooling, of condenser water. In a number of plants, considerable reliance has been placed upon the mechanical settling unit as an integral part of flume water recirculation systems. Use of mechanical clarifiers is widespread, as are earthen ponds to provide settling for flume water recycle systems. The British Columbia Research Council although reporting favorable results with mechanical and pond settling devices concluded that tare recovery and disposal are an ever-continuing problem. The Council suggested that soil buildup within the plant could be eliminated only by physical transport of the soil in the opposite direction to the fields. In the future it is possible that the sugar beet producing farmer may be required to retrieve sludge solids from the processing plant system equivalent to his incoming tare. Elimination or minimization of soil loads on incoming beets is an integral part of best technology for overall pollution control for the beet sugar processing subcategory of the sugar processing point source category.

Typical Process Waste Characterization

The most widely recognized and representative data of waste characterization for the beet sugar processing subcategory of the sugar processing point source category is included in "An Industrial Waste Guide to the Beet Sugar Industry" published by the U.S. Public Health Service. These waste data are included in Table VI. The waste loads are representative of once-through water use without recycling or treatment. The data given in Table VI serve as a reliable base for determining the total waste load potential of a beet sugar processing plant. Because of the wide diversity of in-plant control, recycling, and treatment practices at present beet sugar processing plants the data in Table VI do not reflect the combination of conditions existing at any single plant within the industry today. The data do reflect total waste load and waste water flow values associated with the individual waste source components, which may be predicably amended by various methods of controlling and handling these individual waste water sources within the industry. The total potential waste load and water requirement attributed to each of the waste producing production processes has particular significance and constancy throughout the industry. In addition to providing a baseline of total pollutional load attributed to individual waste components the data also serve to provide a basis for comparison between former and current waste handling techniques.

The former practice of beet sugar processing plants of discharging wastes containing between 15 and 20 kg BOD_5/kkg (30 and 40 lbs/ton) of beets sliced had been reduced to an average of less than 2.5 kg (5 lbs) by 1968. A further reduction in BOD5 load has taken place in most recent years with all plants soon to accomplish a discharge from zero to less than 1.0 kg BOD_5/kkg (2.0 lbs/ton) of beets sliced to surface streams. The total waste discharge to streams from the entire beet sugar processing industry in the United States in 1968 was estimated at about 215 billion l (57 billion gal) which contained a total of about 37 million kg (82 million lb) of BOD_5. However, the 24 million kkg (26 million ton) crop in 1968 was unusually large -- a more normal crop would have been about 20 million kkgs (22 million tons) of beets processed. A number of plants currently recycle much of the flume and condenser waters and some plants do not discharge any waste water to navigable waters at all.

The waste water flow data and waste load information in Table VI (and supported by data from other sources) are adopted as base total flow data and total waste load data associated with beet sugar processing for purposes of this document. Information generally supporting these data and supplemental information regarding characteristics of beet sugar processing plant wastes are summarized in Table VII. The effects of current practices of in-plant control, recycling, and reuse of waste waters within beet sugar processing plants on waste water contribution and characteristics are discussed in the following section. Values for waste water constituents are given to illustrate the variability of waste water qualities and quantities experienced in practice as dependent upon in-process control practices. Every beet sugar processing plant today employs some degree of waste water recycling or reuse.

Under present practices, process waters (pulp screen water, pulp press water, and pulp silo drainage), Steffen waste, and lime mud slurry have essentially been eliminated as polluting waste sources in terms of discharge to navigable waters. Process waters are universally recycled within the plant. Steffen waste is disposed of with by-product use or land disposal, and lime mud slurry receives land disposal. Flume water and barometric condenser water are presently the two primary polluting waste water sources.

Raw Waste Characteristics of Specific Operations

Flume Water

Flume water consists of beet transport water as well as various miscellaneous small waste streams generated within the plant. These include excess cooling water, pump gland leakage, accidental spills, beet washings and spray table overflows. This mixture when discharged from the flume water system is called spent flume water and is generally considered the main plant waste stream.

The Industrial Waste Guide (49) describes waste values for flume water of 9,800 liters (2,600 gal) and 2.25 kg BOD_5/kkg (4.5 lb/ton) of beets processed in the United States. The British Columbia Research Council investigated flume waters of many plants both in the United States and Canada. Plants with a high degree of recirculation as well as those with once-through systems were included. The BOD_5 levels of these waters ranged between 115 and 1525 mg/l and averaged 565 mg/l; the suspended solids content ranged from a low of 127 mg/l to a high of 4500 mg/l; the average was 210 mg/l. In Europe the value was 2.5 kg BOD_5/kkg (5.0 lbs BOD_5/ton) of beets sliced.

TABLE VII

CHARACTERISTICS OF BEET SUGAR PROCESSING PLANT WASTES (1

Characteristic	Flume Water	Barometric Condenser Water	Pulp Screen Water(6	Pulp Press Water	Pulp Silo Drainage	Total Process Waste Water	Lime-Cake Slurry	Lime-Cake Lagoon Effluent	Steffen Waste	General Water Analysis
Volume, gal/ton	2200(3	2000(5	400(5	180(5	210(5	660(3	90(5	75(5	120(3	
Beets	2000-3000(2 2600(5	2400 (1				325(2	75(3			
BOD, mg/l	200(3 200(2 210(5	40(5 30(7	910(5 1020(2	1710(5	7000(5	1230(3 1600(2	8600(5 1420(3	1420(5	10,500(5 10,000(3	445(4
Suspended solids mg/l	800(3 400(2 800-6300(5	77(7		420(5	270(5	1100(3 1300(2	120,000(5	450(3	700(3 100-700(5	4920(4
Total solids, mg/l	1580(3	153(7				2220(3 3800(2	3310(3		43,600(3	6470(4
Volatile solids, %	35(2	86(7				75(2				
COD, mg/l	175(2					1500(2				
Protein-N, mg/l	10(2					65(2				
NH_3-N, mg/l	3(2	6.8(7				15(2				
Kjeldahl Nitrogen mg/l		9.4(7								
Nitrite Nitrogen mg/l		2.6(7								
Nitrate Nitrogen mg/l		0.2(7								
Total Phosphorus mg/l		0.06(7								
Color		5(7								
Turbidity		18(7								
Sulfate, mg/l		203(7								
Chloride, mg/l		35(7								
Sucrose, mg/l	100(2					1500(2				
Dissolved solids mg/l	780(7	780(7				1120(3	2850(3		42,900(3	
pH		6.5								7.9
Alkalinity, mg/l		296(7								250(4
Temperature, °C		39(7								
Total coliform MPN/100ml.		1424(7								
Fecal coliform MPN/100ml.		163(7								
Fecal strep. MPN/100ml.	1334(7									

(1 Represents typical characteristic values of beet sugar wastes prior to treatment

(2 As reported by Pearson, E., and C. N. Sawyer, "Recent Developments in Chlorination in the Beet Sugar Industry," Proceedings of 5th Industrial Waste Conference, Purdue University (November 1949, p.110.

(3 As reported by Elridge, E.F., Industrial Waste Treatment Practice, New York - McGraw-Hill Book Co., Inc., 1942, p. 84.

(4 As reported by Rodgers, H.C., and L. Smith, "Beet Sugar Waste Lagooning," Proceedings of 8th Industrial Waste Conference, Purdue University May 1953, p. 136.

(5 As reported by U.S. Public Health Service, "An Industrial Waste Guide to the Beet Sugar Industry," 1950 (48)

(6 Water - transported pulp in lieu of mechanical conveyor.

(7 As reported by Brenton, R.W., Condenser Water Survey, 1971 - 1972 campaign for beet sugar processing plants of The Great Western Sugar Co., March 1972 (47).

(8 Use of continuous - type diffusers is assumed - a universal practice in the industry today.

Investigations have shown an increase in BOD_5 values of flume waters during the campaign. These increases are mainly attributed to the release of soluble organic matter from frozen beets or those deteriorating as a result of poor storage conditions in northern regions. The leaching losses of sugar into the flume water are also associated to some degree with the temperature of the flume water. To minimize this effect, cold fresh water is used for makeup in some plants. In others, barometric condenser water is first discharged through a cooling tower before being used for makeup in the flume system. However, when frozen beets are to be sliced they are usually thawed with the hot barometric condenser water. Studies in Minnesota showed that the average BOD_5/unit weight of beets processed varied from 1.0 to 2.2 kg/kkg (2.0 to 4.4 lb/ton) at the beginning of the campaign to 4.6 to 5.14 kg/kkg (9.2 - 10.3 lb/ton) near its end. The "leveling off" of the BOD_5 in recycled flume water systems at many plants within the 6,000 - 7,000 mg/l range has been well established through estensive studies. It has been shown that for BOD_5 concentrations greater than 25 mg/l in flume water, the COD may be predicted at 150 percent of the BOD_5 concentration. COD concentrations in recirculated flume water systems range between 9,000 and 10,000 mg/l.

Flume waters vary considerably in their content of soil, stones, beet leaves, roots, and dissolved solids between locations and harvesting conditions and from season to season. During fluming large quantities of detritus are removed from the beets. Under certain conditions when incoming beets have great quantities of adhering soil, the flume water consistency may approach that of a slurry because of its solid content. In more favorable dry harvesting seasons, particularly in areas of light sandy soil, the adhering soil may only be 3 or 4 percent by weight when the beets are received at the plant, but during wet harvesting seasons, soil may range up to 20 percent by weight. The average soil tare ranges from 5 to 6 percent. As a result, a typical plant may receive about 19,900 kkg (22,000 tons) of incoming tare over the average campaign.

The basic flume water recycling system was first in operation at Brighton, Colorado, and was later firmly demonstrated at the Longmont, Colorado, plant of the Great Western Sugar Company under a project sponsored by the Beet Sugar Development Foundation and the Federal Water Pollution Control Administration. After overcoming initial mechanical operational problems in handling water surges, the system operated successfully. Recirculation of flume water is now a common practice within the beet sugar processing industry and involves lime addition for pH control, screening, settling to remove settleable solids, and discharge of solids to control buildup in the recirculation system. Large organic particles removed by screening are recovered for byproducts such as cattle feed.

Dissolved solids content of the flume water generally increases through the first 6 weeks of operation of the closed system, reaching the observed maximum total dissolved solids concentration of approximately 9,000 to 10,000 mg/l. As also previously noted, the BOD_5 level tends to reach an equilibrium concentration in the range of 6,000 to 7,000 mg/l during the campaign.

A number of studies have related bacterial densities that have been found on the outer surfaces of beets, and associated dirt, trash, and fertilizers at beet sugar processing plants in the Red River of the North. Total coliform bacteria determinations indicate that the dirt from freshly unloaded beets contained 490,000 organisms per gram of solid material. Very high total coliforms were found on the surfaces of the sliced beets and on the beet trash removed from the flume water. These levels were 13,000,000 and 17,200,000 total coliforms per gram of material, respectively.

The bacterial loads varied from 0 to 68 Bacterial Quantity Units (BQU) of total coliform bacteria discharged per 110 kkg (100 ton) of beets sliced, and fecal coliform bacteria from 0 to 8.4 BQU discharged per 93 kkg (100 ton) of beets sliced. For comparative purposes, the raw sewage discharged by a human population of 1,000 persons would be expected to contain around 15-30 BQU of total coliform bacteria and 5-20 BQU of fecal coliforms . Relatively low bacterial loads have been attributed to some plants because of lime addition, contributing to very high pH levels in the total plant wastes. The field surveys have shown that pH levels exceeding 9.0 are particularly destructive to organisms of the coliform group.

Studies of fecal coliform to fecal streptococci ratios of sampled final waste discharges indicate bacterial pollution to be primarily and originally derived from the fecal excreta of animals rather than humans. The source of such pollution would be from livestock animals such as found on farm feedlots and stockyards or from storm water runoff. Sugar beet wastes have been found to contain Streptococci bovis, a species strongly associated with the feces of cattle and other domestic animals. Within the plant, river water used for fluming and washing purposes may represent another source of fecal coliforms. These bacteria were found to originate generally from up-stream domestic wastewater discharges. The bacterial population found in beet sugar processing plants and in associated waste streams are introduced largely into the plant through the flume water system. From the flume water they are transferred through the beet washer, spray table, and beet slicer to the diffuser.

An extremely favorable environment is created in the fluming system for sustaining and enhancing bacteria growth by an abundance of nutrients, favorable temperatures, stagnant zones, and the availability of fixed surfaces. Control is easily achieved in the diffuser with formalin or other biocide treatment. Total bacterial destruction is accomplished by the subsequent heat effects in the evaporation process.

In the continuously recycled flume water system, the underflow volume (approximately 20%) has been demonstrated to compensate for the buildup of dissolved and suspended solids and BOD_5 in the recycled flume water. As a result the buildup to equilibrium concentrations presents no problem in the beet sugar processing and sugar production operation. However, to avoid contamination, the flume water must not enter the diffusion unit operation and fresh water is used on a final spray wash of the beets before processing to assure no contamination.

The practice of discharging approximately 20% blowdown for solids control in recirculating flume water systems is widely supported by experience in the beet sugar and cane sugar processing industries as well as recirculating process water systems employed by other similar industries. This figure serves as a generally industry accepted value for needed blowdown to effect satisfactory solids control with fresh water makeup in this type of system.

Lime Mud Slurry

Hydrated lime is added to the raw juice as a purifying agent and then precipitated by carbon dioxide in the carbonation process. The resulting calcium carbonate sludge, with impurities removed from the juice, is vacuum filtered and slurried with water. This mixture is known as lime mud waste, lime-cake, or lime slurry residue. Steffen house plants use two to three times the quantity of lime employed in straight-house operations, and the lime-cake slurry is reported by studies of the Federal Water Pollution Control Administration to be about 50 percent higher in BOD_5 strength. Sludges from the concentrated Steffen filtrate process and boilouts from the cleaning of evaporators and vacuum pans may also be added to the lime mud for disposal.

Lime mud slurry or sludge is alkaline with extremely high organic and suspended solids content. Besides calcium carbonate, the sludge includes pectins, albuminoids, amino acids, other nitrogenous and proteinaceous compounds, and a significant amount of impure sugars. A study of 59 plants in the U.S. and Canada showed lime mud slurries to have an average BOD_5 of 6,370 mg/l with a range of 1,060 to 27,800 mg/l. The suspended solids content of these slurries averaged 229,000 mg/l with a range from 143,000 to 357,000 mg/l. Amounts of water added to the filter cake from the vacuum filter varied greatly and were mainly responsible for the wide range demonstrated in BOD_5 and total suspended solids values.

Lime mud slurry may be expected to have unit waste values of 340 liters (90 gal) and 3.3 kg BOD_5/kkg (6.5 lbs BOD_5/ton) of beets sliced (49). From experiences in Europe and Great Britain both lower and higher BOD_5 values have been reported. A survey conducted by The Federal Water Pollution Control Administration on beet sugar processing plants in the South Platte River Basin in Colorado showed that lime mud wasting from a Steffen house plant could add about 2.5 kg (5 lbs) BOD_5, 3.5 kg (7 lbs) COD, 45 kg (90 lbs) total suspended solids (TSS), and 22.5 kg (45 lbs) of alkalinity per 1.1 kkg (ton) of beets processed to the basic plant loads. A straight-house plant would result in one-half to three-fourths of these respective levels.

Lime cake generated from juice purification operations amounts to about 5.0 percent of the weight of beets processed in U.S. and European practice. A plant handling 136,000 kkg (150,000 tons) of beets over the season could produce 2000-4100 kkg (2200-4500 tons) of lime-cake. The weight of slurry would be considerably# greater. The pollutional strength of lime mud slurries vary widely among beet sugar processing plants, depending in large part on the amount of water used in diluting the filter cake.

Steffen Filtrate

Steffen waste results from the extraction of sugar from the straighthouse molasses by the Steffen process. Steffen filtrate (the source of wastes) originates from the filtering of saccharate cake in the precipitation of diluted molasses in the Steffen house.

The Steffen filtrate through the 1940's represented the most damaging waste product from the beet sugar processing plant. The filtrates are highly alkaline with a pH level near 11, with 3 to 5 percent organic solids. The Industrial Waste Guide (49) describes Steffen filtrate as containing around 10,500 mg/l BOD_5, 25,000 to 40,000 mg/l total solids, and 100 to 700 mg/l total suspended solids.

The South Platte River Basin studies conducted by the Federal Water Pollution Control Administration showed that elimination of Steffen waste from the effluent by concentration and disposal as a cattle feed supplement reduced the pollution load of Steffen operations by about 115 kg of BOD_5/kkg (230 lb of BOD_/ton) of molasses worked.

Condenser Water

Barometric condenser water is employed in multiple effect evaporators and across the vacuum pans to create vacuum for low temperature boiling of sugar solutions in the sugar production process. Steam and vapors from the fifth-effect of the multiple effect evaporator and from the vacuum pans are condensed by direct contact with the water passing through the barometric condenser. The condenser water remains relatively unchanged except for an increase in temperature to 50-65°C (122-149°F) (65). However, condenser waters generally accumulate some entrained solids and absorb ammonia from the evaporating juices.

They are always alkaline, with a pH range from 8 to 10, but usually are less than 9.

The principal waste constituents in barometric condenser water include BOD$\underline{5}$, ammonia nitrogen, and sometimes phosphates from water treatment. Total solids are of importance in a "recycled" condenser water system. Ammonia, organics, and phosphorus are important in the eutrophication process and have a potential degrading influence on streams and lakes.

Data regarding the BOD$\underline{5}$ content of condenser water confirm previous findings, namely, that sugar lost by entrainment amounts to about 820 kg (1800 lbs) per day in a plant of 2300-2700 kkg (2500-3000 ton) capacity. Suspended solids in the condenser water which leaves the seal tank are low. The British Columbia Research Council study on various plants reported an average BOD$\underline{5}$ for condenser waters of 43 mg/l with a range of 25 to 130 mg/l BOD$\underline{5}$. Another study found an average BOD$\underline{5}$ of 50 ppm or less (65); a third reported 30 mg/l (74). Ammonia nitrogen concentration approached 3-15 mg/l as nitrogen with good operation. Suspended solids averaged 67 mg/l with a range from 0 to 100 mg/l.

The concentration of organics in condenser water with complete recirculation has reached an equilibrium concentration near 25 mg/l BOD$\underline{5}$ in present recirculation systems and has not been an operational problem. Degradation of biodegradable organics will occur in various cooling devices such as cooling towers, aeration ponds, or open cooling ponds designed primarily for cooling.

Experience indicates that accidents, shock loads, etc., cause heavy vapor entrainment into condenser waters, and these conditions are reflected in the waste loads. When overloading occurs, pan condensers receive intermittent quantities of liquor that boil over during the various stages of the boiling cycle. More carryover of organics into condenser water is generally experienced in the fall in the North and North Central United States as a result of beet deterioration. Based upon U.S. and European practices, good control procedures will lower the condenser BOD$\underline{5}$ concentration to 15-30 mg/l (13). Better operation with entrainment control devices can limit the degree of entrainment to 10-15 mg/l.

The source of fecal coliforms if present in condenser water would originate from the water supply source and generally would be of concern only where surface waters containing bacteriological contamination are used as the source of condenser water. The elevated temperatures with small entrainment of organics from the barometric condensers present favorable conditions for the growth of bacteria in the condenser water. However, because of its relative purity in comparison with other waste waters, condenser water is frequently used for both diffuser supply and flume water makeup. The latter practice is especially necessary in cold climates when processing frozen beets. The elevated temperatures resulting from use of water for barometric condensing eliminates serious concern as to the presence of pathoganic organisms in the waste water after use.

The practice of reuse of condenser water has increased in recent years. In 1968, 38 of the 58 beet sugar processing plants used condenser water for fluming and other in-plant uses; 20 cooled and recycled this water to condensers. Many plants made some in-plant use of condenser water and discharged the remainder to surface waters. At present, 35 of 52 plants employ complete or partial recycling or reuse of condenser water; 32 plants utilize cooling devices of which 16 also employ maximum recycling for condenser water for condensing purposes.

In most plants the condenser and cooling water systems are the principal sources of makeup water supply for the beet flumes and for beet washing. When not reused for fluming and beet washing, condenser water becomes another waste source. Its volume is substantially reduced by recycling.

Extensive recycling of condenser water requires some additive control measures in areas where the water is of poor or marginal quality. As recycling is increased, the scaling properties are increased by the concentration of solids through evaporation and by increased pH from the absorption of ammonia. Although most plants use some type of polyphosphate threshold treatment to prevent scaling, it may also be necessary to reduce the pH with acid.

The problem of dissolved solids accumulation may be controlled (and is generally accomplished in the industry) through periodic bleed-off (approximately 10 percent) of water from the system in order to maintain acceptable total dissolved solids levels (approximately 10,000 mg/l or less) for scaling control. Fresh or clean water make up is necessary.

Various means of cooling are employed, such as spray ponds, open ponds, and natural draft and induced draft cooling towers. The latter are generally necessary in warmer and more humid climates. In most cases, it is not possible to provide recycled water at as low a temperature as the normal primary cold water source. Because of this, the recycle system generally requires the addition of low temperature make-up water.

The use of cooling towers for condenser water recycling usually presents a potential problem in the growth of slime-producing organisms in the tower packing. In the presence of small amounts of sugar and other nutrients and with warm temperatures the growths are difficult to control. Under the most adverse conditions of processing extremely deteriorated beets the foaming tendency of beet liquors may likely be increased substantially so as to complicate the control and minimization of vapor entrainment into barometric condenser waters. At such times conventional entrainment separators may become less effective with increased carryover of organics in the barometric condenser water system. The tendency of sugar liquors to foam requires efficient vapor entrainment separators in order to preclude the loss of significant quantities of sugar to the condenser water (28). The entrainment produced by boil-over and foaming can produce substantial shock loading of BOD_5 in the effluent condenser water. These two hazards necessitate careful and frequent analysis of condenser water for sugar in order to obviate the problem. Superior entrainment separators and mist eliminators will aid materially in the reduction of condenser water contamination by sugar. The additional use of level controllers on some equipment will assist materially in reducing contamination that originates from human error.

Miscellaneous

Various sources of wastewater other than those previously described are generated in a beet sugar processing plant. These waste sources are of less importance in load and volume than those previously described and result from gas scrubber washing, miscellaneous cooling waters, flyash, juice water, waste water from cleaning of boilers, and floor washing.

Potable quality water is not necessary for gas washing, but a sizeable volume of water is used. Crane of the British Sugar Corporation reports the reuse of clarified flume water in the gas washer, after which it is returned to the unclarified flume water portion of the system.

Crane also notes that selected cooling waters such as those used for cooling turbine oil can be recirculated through a separate cooling tower. Many of the other cooling water streams may be recycled to the main cooling tower and reused. Where furnace ash (flyash) is conveyed with water, a complete recirculatory system is reported. A separate settling pond is provided where the water is decanted and recycled.

Periodic (weekly or biweekly) cleaning of pan evaporators to eliminate accumulated scale is accomplished by using caustic soda followed by acid treatment in the cleaning process with the discharge of "boil-outs" generally being sent to the flume system or lime mud slurry pond.

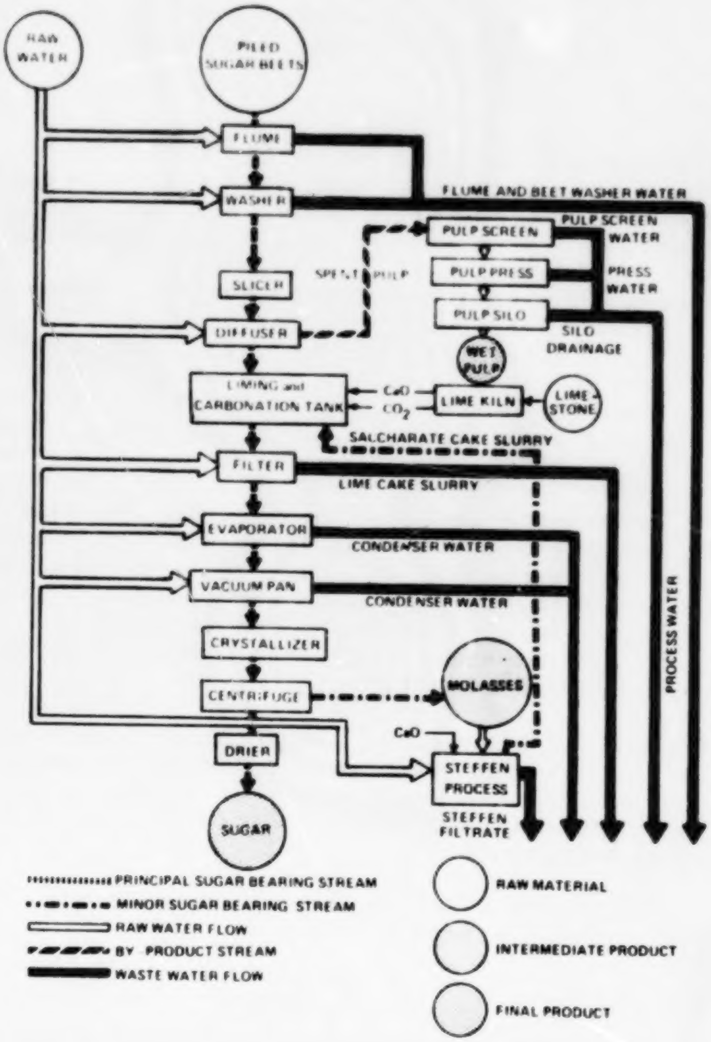
The primary source of water for miscellaneous use is condensate and excess condenser waters.

Process Flow Diagrams

A schematic diagram of the beet sugar processing operation is given in Figure II. The flow diagram reflects a situation in which no recirculation or treatment of individual waste water streams is practiced and corresponds with the waste loads given in Table VI. The hypothetical plant includes the Steffen process. The three pulp waters (pulp screen water, pulp press

Figure II

MATERIALS FLOW IN A BEET SUGAR PROCESSING PLANT WITH NO RECIRCULATION OR TREATMENT OF WASTE WATERS— STEFFEN PROCESS [1]


RAW WATER
PILED SUGAR BEETS
FLUME
WASHER
FLUME AND BEET WASHER WATER
PULP SCREEN
PULP SCREEN WATER
PULP PRESS
PRESS WATER
SLICER
SPENT PULP
PULP SILO
SILO DRAINAGE
DIFFUSER
WET PULP
LIMING and CARBONATION TANK
CaO
CO_2
LIME KILN
LIME-STONE
SACCHARATE CAKE SLURRY
FILTER
LIME CAKE SLURRY
EVAPORATOR
CONDENSER WATER
VACUUM PAN
CONDENSER WATER
PROCESS WATER
CRYSTALLIZER
CENTRIFUGE
MOLASSES
CaO
DRIER
STEFFEN PROCESS
STEFFEN FILTRATE
SUGAR
PRINCIPAL SUGAR BEARING STREAM
MINOR SUGAR BEARING STREAM
RAW WATER FLOW
BY PRODUCT STREAM
WASTE WATER FLOW
RAW MATERIAL
INTERMEDIATE PRODUCT
FINAL PRODUCT

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[1] As taken from Beet-Sugar Technology, Second Edition, Edited by R.A. McGinnis, Beet-Sugar Development Foundation, Fort Collins, Colorado (1971) (65)

water, and pulp silo drainage) are commonly referred to as process water. Since the stipulated conditions are without recirculation, maximum conditions of water requirement and waste water disposal are indicated.

A schematic of materials flow in a common recirculation system of a beet sugar processing plant is indicated in Figure III. Variations in this scheme of recycling waters as practiced within present plants are indicated in Figures IV through VI. The diagrams are presented with emphasis on direct process related uses of water within the beet sugar processing plant. Other water uses (e.g. boiler supply water, hot water for floor and evaporator cleaning, gas washer water, etc.) are not indicated on the diagrams for sake of simplicity. Boiler supply water, diffuser make-up, and hot water for cleaning purposes are supplied through in-plant water reuse or fresh water sources (primarily the purer condensate waters from juice evaporation). A more detailed description of other water uses is included in Mass Water Balance in a Beet Sugar Processing Plant, Section VII of this document.

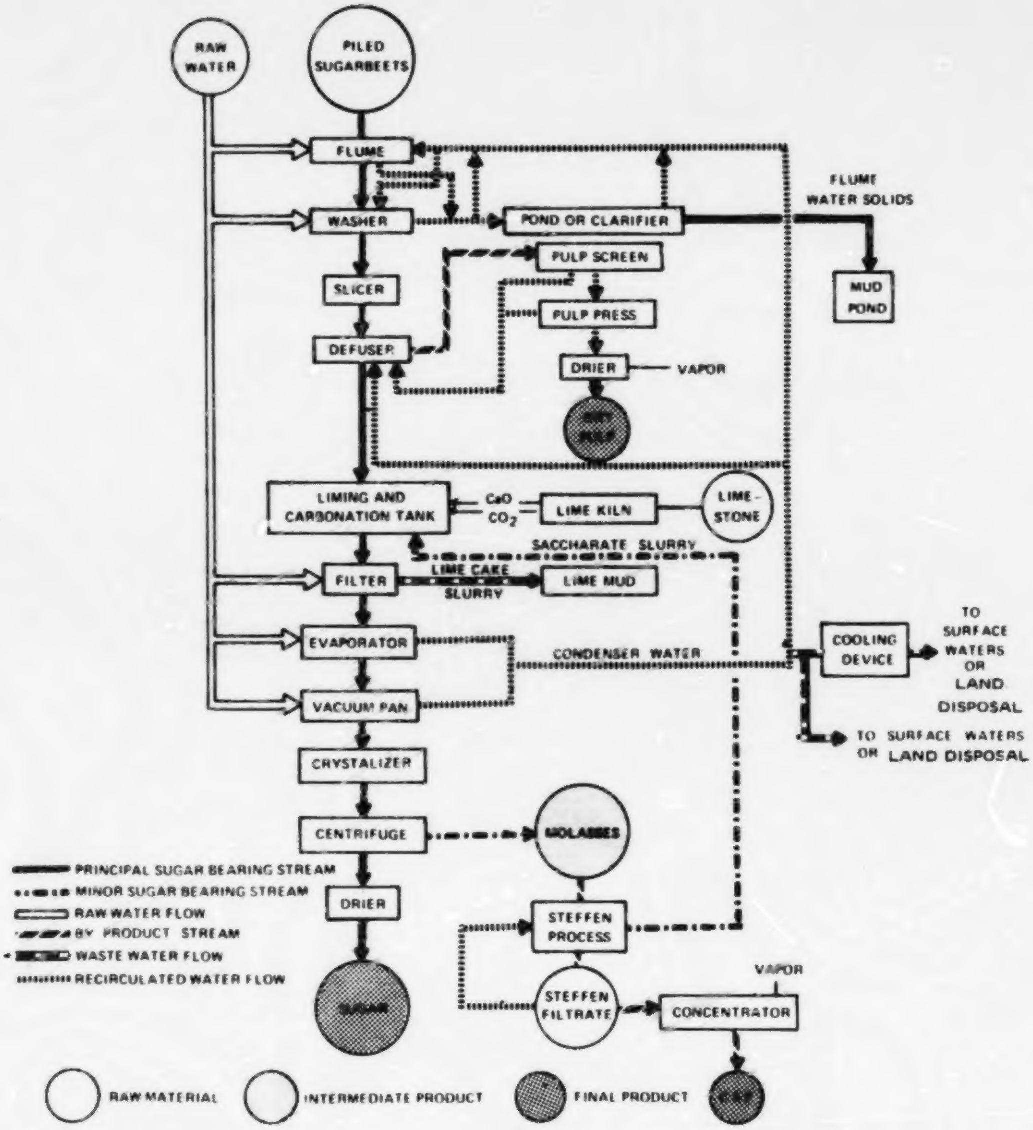
Figure IV represents a water flow scheme in the industry. In this type of flow scheme, all the fresh water is used in the barometric condensers of evaporators and pans, for miscellaneous cooling, and at Steffen plants for dilution of molasses. Spent condenser water is used for fluming and washing beets, for makeup in the diffuser, and for other purposes. Plants employing this sequence of water use are equipped with continuous diffusers, pulp screens, pulp presses, and pulp driers. Pulp press water is returned to the diffuser. Settling ponds for removing soil from spent flume water and ponds for collecting lime mud are provided. The overflow from ponds and any excess condenser water may be discharged to streams.

Figure V represents a flow pattern involving more nearly complete reuse of water. Fresh water is used only in evaporator and crystallization pan condensing, for some miscellaneous cooling, and at Steffen plants for dilution of molasses. During the campaign, flume water after screening is pumped to settling ponds and after more or less complete removal of settleable solids is returned to the flume. Water from the evaporator and pan barometric condensers is used as makeup water in the diffuser, in the beet washers, and in sprays. Pulp water and pulp press water are returned to the diffuser. Lime mud is pumped to a separate lime pond. Most of the condenser water is cooled by cooling tower or spray pond and recycled to condensers. Steffen waste is evaporated to concentrated Steffen filtrate.

Figure VI represents an extensive recirculation pattern of flow, except that at the end of the operating campaign ponds may be drained to municipal sewage treatment plants or land disposal.

Figure III

MATERIALS FLOW IN BEET SUGAR PROCESSING PLANT WITH TYPICAL WATER UTILIZATION AND WASTE DISPOSAL PATTERN [1]


RAW WATER
PILED SUGARBEETS
FLUME
WASHER
POND OR CLARIFIER
FLUME WATER SOLIDS
MUD POND
PULP SCREEN
SLICER
PULP PRESS
DEFUSER
DRIER
VAPOR
LIMING AND CARBONATION TANK
CaO
CO_2
LIME KILN
LIME-STONE
SACCHARATE SLURRY
FILTER
LIME CAKE SLURRY
LIME MUD
EVAPORATOR
CONDENSER WATER
COOLING DEVICE
TO SURFACE WATERS OR LAND DISPOSAL
VACUUM PAN
TO SURFACE WATERS OR LAND DISPOSAL
CRYSTALIZER
CENTRIFUGE
MOLASSES
PRINCIPAL SUGAR BEARING STREAM
MINOR SUGAR BEARING STREAM
RAW WATER FLOW
BY PRODUCT STREAM
WASTE WATER FLOW
RECIRCULATED WATER FLOW
DRIER
SUGAR
STEFFEN PROCESS
STEFFEN FILTRATE
VAPOR
CONCENTRATOR
RAW MATERIAL
INTERMEDIATE PRODUCT
FINAL PRODUCT

[1] As taken and modified from Beetsugar Technology, Second Edition, Edited by R.A. McGinnis, Beetsugar Development Foundation, Fort Collins. Colorado (p 645), 1971, (65)

Figure IV

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH MINIMUM RECYCLE OR REUSE

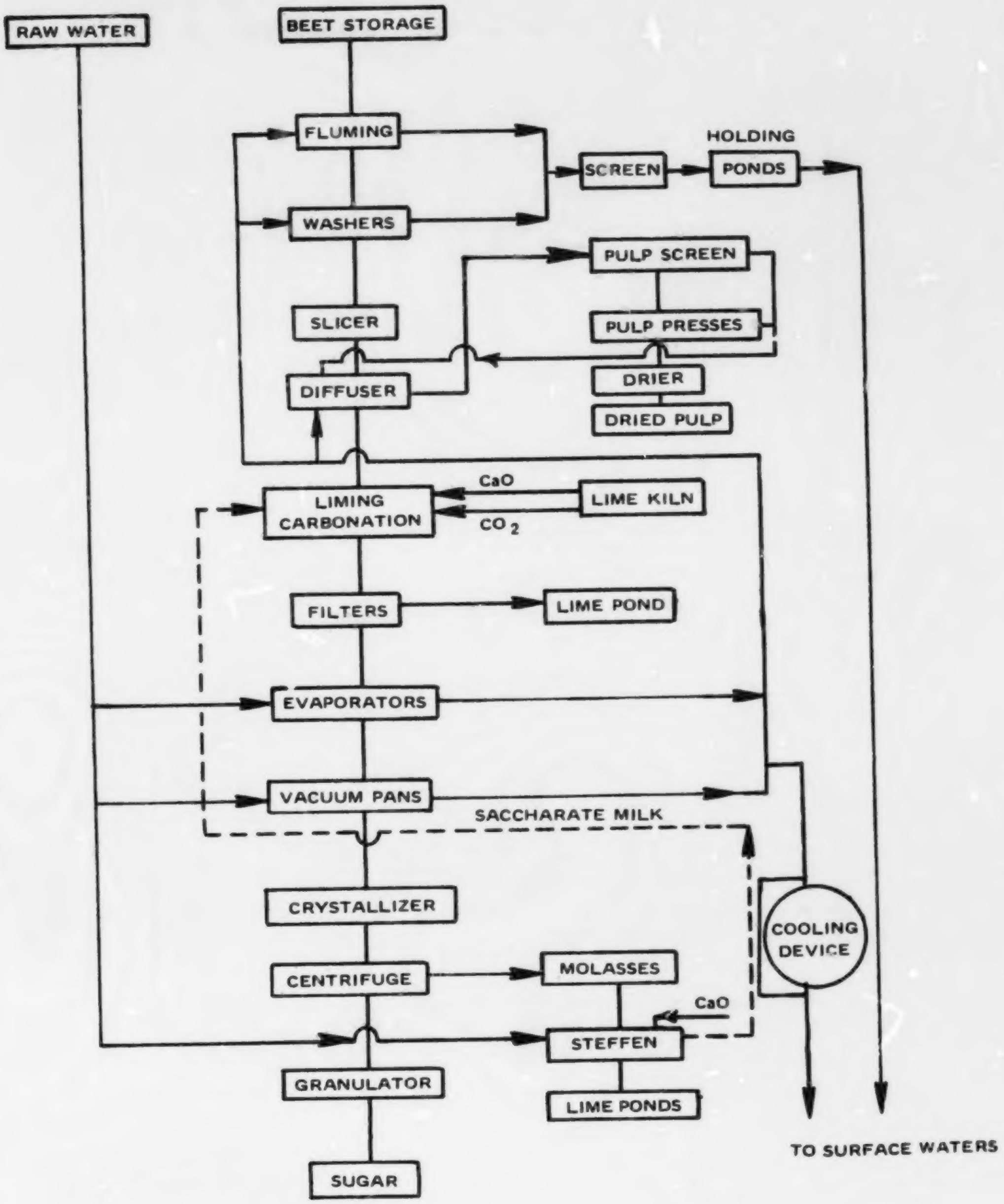

RAW WATER
BEET STORAGE
FLUMING
HOLDING
PONDS
SCREEN
WASHERS
PULP SCREEN
SLICER
PULP PRESSES
DIFFUSER
DRIER
DRIED PULP
CaO
LIME KILN
LIMING
CARBONATION
CO 2
FILTERS
LIME POND
EVAPORATORS
VACUUM PANS
SACCHARATE MILK
CRYSTALLIZER
COOLING
DEVICE
CENTRIFUGE
MOLASSES
CaO
STEFFEN
GRANULATOR
LIME PONDS
TO SURFACE WATERS
SUGAR

Figure V

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH SUBSTANTIAL IN-PROCESS RECYLE AND REUSE

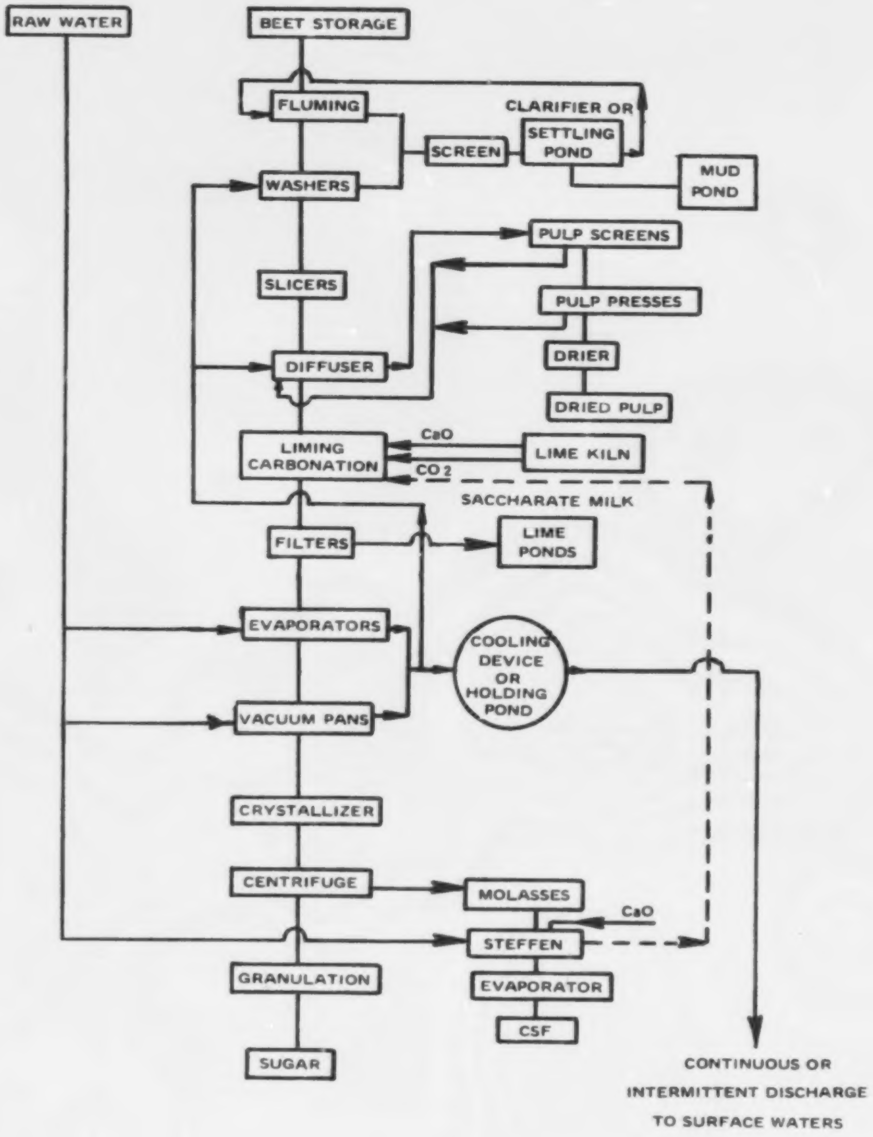
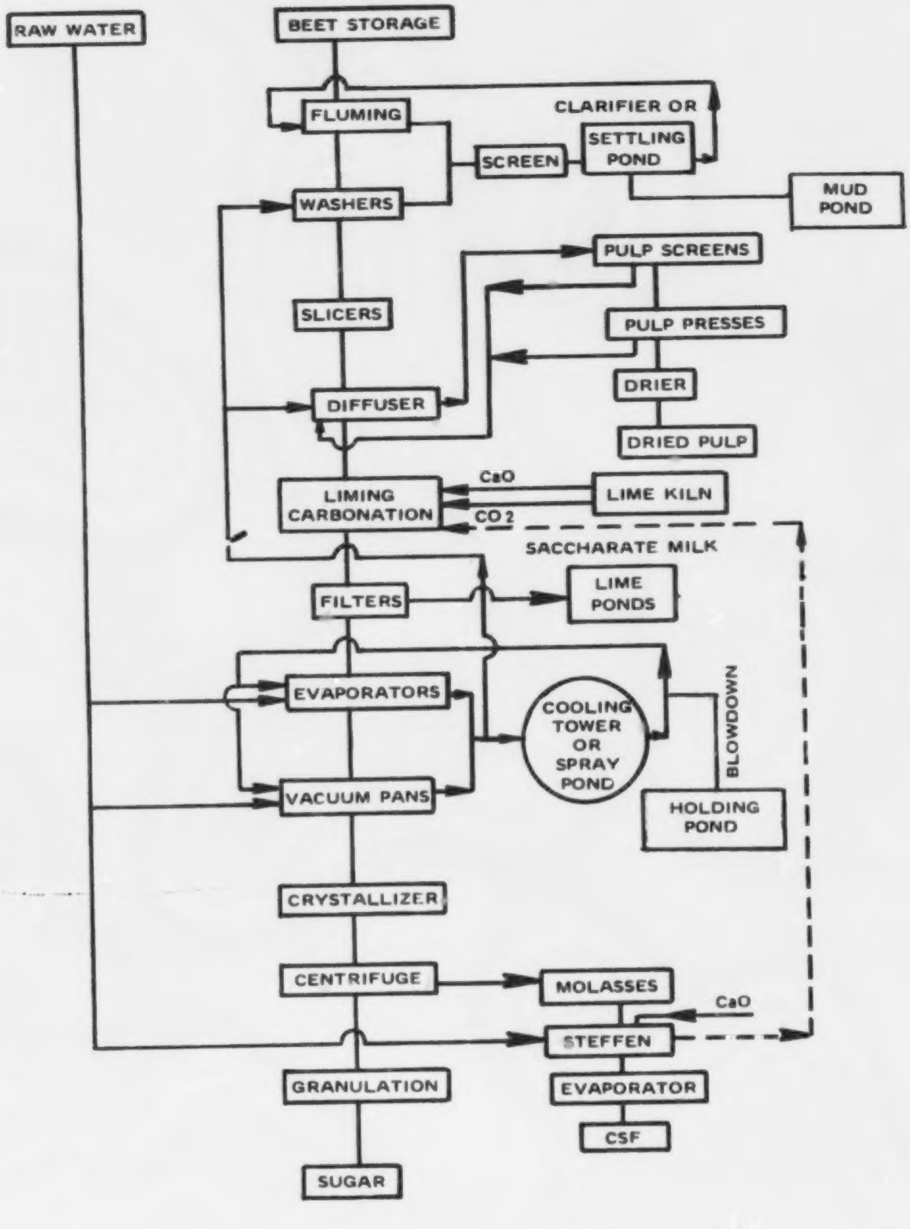

RAW WATER
BEET STORAGE
FLUMING
CLARIFIER OR
SETTLING POND
SCREEN
MUD POND
WASHERS
PULP SCREENS
SLICERS
PULP PRESSES
DIFFUSER
DRIER
DRIED PULP
LIMING CARBONATION
CaO
LIME KILN
CO2
SACCHARATE MILK
FILTERS
LIME PONDS
EVAPORATORS
COOLING DEVICE OR HOLDING POND
VACUUM PANS
CRYSTALLIZER
CENTRIFUGE
MOLASSES
CaO
STEFFEN
GRANULATION
EVAPORATOR
CSF
SUGAR
CONTINUOUS OR INTERMITTENT DISCHARGE TO SURFACE WATERS

Figure VI

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH MAXIMUM IN-PROCESS AND DISCHARGE CONTROLS


RAW WATER
BEET STORAGE
FLUMING
CLARIFIER OR
SETTLING POND
SCREEN
MUD POND
WASHERS
PULP SCREENS
SLICERS
PULP PRESSES
DRIER
DIFFUSER
DRIED PULP
CaO
LIMING CARBONATION
LIME KILN
CO2
SACCHARATE MILK
FILTERS
LIME PONDS
EVAPORATORS
COOLING TOWER OR SPRAY POND
BLOWDOWN
VACUUM PANS
HOLDING POND
CRYSTALLIZER
CENTRIFUGE
MOLASSES
CaO
STEFFEN
GRANULATION
EVAPORATOR
CSF
SUGAR

SECTION VI

POLLUTANT PARAMETERS

Pollutant and Pollutant Parameters

Upon review of available EPA and industry data and information gathered during on-site plant surveys by EPA personnel the following chemical, physical, and biological properties or constituents have been found to exist in significant quantity in process waste water from the beet sugar processing subcategory:

BOD$\underline{5}$ (5-day, 20°C Biochemical Oxygen Demand)
COD (Chemical Oxygen Demand)
Total Coliforms
Fecal Coliforms
pH
Temperature
Alkalinity
Ammonia Nitrogen and Other Nitrogen Forms
Total Phosphorus
Total Dissolved Solids
Total Suspended Solids

On the basis of all evidence reviewed, there do not exist any other pollutants (e.g., heavy metals, pesticides) in wastes discharged from beet sugar processing plants.

The equilibrium concentration of BOD$\underline{5}$ in a completely recycled flume water system is generally found to be quite high (6,000 to 7,000 mg/l). The BOD$\underline{5}$ concentration does not build up materially in the recirculating barometer condenser system, and evidence indicates an equilibrum level near the organic entrainment level. Associated biological activity in cooling devices is apparently effective in BOD$\underline{5}$ reduction in the recycled condenser system. It has been shown that for BOD$\underline{5}$ concentrations greater than 25mg/l in flume water the COD may be predicted at 150 percent of the BOD$\underline{5}$ concentration. COD concentrations in recirculated flume water systems range between 9,000 and 10,000 mg/l.

The South Platte River Basin study confirmed that the source of coliform organisms in flume waters is animal manures spread on fields where sugar beets are grown.

Bacteriological characteristics of flume water present no sanitary problems in the production process. In production, high pH conditions maintained in the recycled flume water system, final fresh water wash of incoming beets, use of biocides in the diffuser for pH control, and subsequent destruction of all bacteria in the evaporation process satisfactorily limit and control bacterial growth for production purposes. If fecal coliform bacteria are present in surface waters which serve as the water supply for condensers, prolific bacterial growth will

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occur in the heated condenser water with the normal concentration of organics through vapor entrainment. Bacteriological qualities of waste waters are not normally a pollution problem where inplant recycling, waste retention and land disposal are practices. More detailed discussion of bacteriological characteristics of beet sugar process waste waters with quantitative evaluation is included in Section VII of this document.

The parameter pH is a very important criterion for frequent measurement in providing in-process quality control (pH between 8 and 11) for efficacious recycling of flume water. High pH conditions help to control odors and inhibit bacterial growth.

The temperature of condenser waters leaving the pan evaporation and crystallization process may approach 65°C (149°F).

Alkalinity is a measure of the presence of bicarbonate, carbonate and hydroxide ions in waste water. Alkalinity of beet sugar processing waste results from the addition of lime in flume water systems and from ammonia entrainment in barometric condenser waters.

Ammonia nitrogen is present in barometric condenser waters (3 to 15 mg/1) as nitrogen under best operation) due to vapor entrainment. With progressive oxidation, ammonia is converted to nitrate nitrogen.

Phosphorus is found in flume waters as associated with incoming soil on beets, and in barometric condenser waters because of addition of de-scaling chemicals and entrainment of vapors from barometric condensers. Surveys by Brenton indicate a total phosphorus concentration in condenser waters of 0.06 mg/l.

Total dissolved solids in recycled flume and condenser waters reach a high equilibrium level of approximately 9,000-11,000 mg/l. Periodic withdrawal of recirculated waste water is required to maintain the equilibrium concentration.

The total dissolved solids contained in the underflow "blowdown" volume of an extensive recycle flume water system have a high concentration of sodium and potassium salts.

Suspended solids as a parameter in completely recycled waste water systems serve most importantly in measuring the efficiency of solid separation devices such as mechanical clarifiers or earthen holding ponds for flume water. The performance of these settling measures is reasonably reliable and dependable. The suspended solids criterion has less importance in determining efficiency of settling, but more importance for use as a control measure in determining the quantity of soil conveyed to the plant on incoming beets and subsequently transferred to the flume (beet transport) water.

Properties of the Pollutants and Pollutant Parameters

The following paragraphs describe the chemical, physical and biological properties of the pollutants and pollutant parameters that exist for the beet sugar processing subcategory. The undesirable characteristics that these parameters exhibit or indicate are stated giving reason as to why they were selected.

Biochemical Oxygen Demand (5-day, 20°C BOD) - This parameter is a measure of the oxygen consuming capabilities of organic matter. The BOD$_5$ does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD$_5$, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD$_5$ indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations is essential not only to keep organisms living but also to sustain species reproduction and vigor and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD$_5$ can kill all inhabitants of the affected area.

If a high BOD$_5$ is present the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms because of the uptake of degraded materials that form the foodstuffs of the algal populations.

Chemical Oxygen Demand (COD) - This parameter is a measure of the quantity of chemically oxidizable materials present in water. In some instances, a rough correlation between COD and BOD$_5$ can be established. Since an oxygen demand is indicated to exists this parameter exhibits the same adverse conditions that may result by BOD$_5$.

Bacteriological Characteristics (Total and Fecal Coliforms) - Fecal coliforms are used as an indicator since they originate from the intestinal tract of warm-blooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms pathogenic to humans and animals may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, chlorea, vibriosis and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent. Salmonella organisms have been isolated in flume (beet transport) wastes.

A problem of pollutional concern in ground waters could conceivably arise in the absence of necessary controlled soil filtration procedures with land disposal of process waste waters. However, no ground water pollution problems are presently known to exist as directly attributed to land disposal and/or application of beet sugar processing wastes. At present a large portion of the process waste waters of the subcategory are disposed of on land in the absence of controlled filtration procedures.

pH, Acidity, and Alkalinity - Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal under a higher condition of pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Temperature - Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development; while warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost attributable to fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a watercourse.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

In summary, heated waste discharges to surface waters create a variety of thermal pollution effects including adverse modification of the aquatic flora and fauna environment with the accompanying increase in the rate of biological reactions, and possible permanent temperature elevations over considerable stream areas with continued added thermal loading. Thermal conditions have considerable effects on the concentration of dissolved oxygen, the biochemical reaction rate, pH, and the physical activity of aquatic animals.

Cooling of barometric condenser waters is necessary before discharge to navigable waters. Where adequate cooling devices are provided for the heated condenser water (often with additional cooling provided by fresh water addition through well or surface water supplies) extensive recycling without surface or ground water pollution can result. However, if greatly heated waste water does reach surface or ground water formations, potentially serious imbalances in micro-ecosystems can occur with upsets of chemical equilibrium.

Ammonia Nitrogen and Other Nitrogen Forms - Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is most toxic in this state. The lower the pH, the more ionized ammonia is formed, and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Ammonia nitrogen in waste water effluent has several undesirable features:

(1) Ammonia consumes dissolved oxygen in the receiving water;

(2) Ammonia reacts with chlorine to form chloramines which are less effective disinfectants than free chlorine;

(3) Ammonia has possible deleterious effects on fish life;

(4) Ammonia is corrosive to copper fittings;

(5) Ammonia increases the chlorine demand of waste waters for subsequent treatment.

Ammonia may be reduced in waste waters by physical methods and converted to nitrates by biological oxidation. A nitrified effluent, free of substantial concentrations of ammonia, offers several advantages:

(1) Nitrates will provide oxygen to sludge beds and prevent the formation of septic odors;

(2) Nitrified effluents are more effectively and efficiently disinfected by chlorine treatment;

(3) A nitrified effluent contains less soluble organic matter than the same effluent before nitrification.

Ammonia and nitrate are interchangeable nitrogenous nutrients for green plants and alage as well as bacteria. At the present time, predictive generalizations cannot be made for the response of algae to nutrients for all receiving waters. Different geophysical systems appear to be responsive to different limiting nutrients. The nitrogen content of natural unpolluted waters is normally less than 1 mg/l, and during the growing season soluble nitrogen compounds are virtually completely depleted by growing plants and algae. Ammonia is rapidly adsorbed by soil minerals, and particulate matter containing nitrogen is also effectively removed in the soil. However, if there is not sufficient plant growth in the soil to use the bound ammonia, it will be converted to nitrates by nitrifying bacteria.

Total Phosphorus - During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element of all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growth. Phosphorus is usually described, for these reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic factors, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bio-accumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l (one microgram per liter).

Even though phosphorus is readily adsorbed tenaciously on soil particles, once in sediment or benthos the phosphorus may desorb to become an available nutrient.

Total Dissolved Solids - In natural waters, the total dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no more suitable water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleanness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Total Suspended Solids - Total suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to aquatic life, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludge worms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute parameter of quickly estimating the total suspended solids when the concentration is relatively low.

In establishing limits, only certain primary parameters have been chosen which include:

BOD$\underline{5}$
pH
Temperature
Fecal Coliforms
Total Suspended Solids

The last two parameters are applicable to limit the maximum permissible discharge of process waste water pollutants when the process waste water discharge results from total composite waste waters including barometric condensing operations and any other beet sugar processing operation. The parameters of fecal coliforms and total suspended solids were not chosen to apply to beet sugar processing operations discharging process waste water from barometric condensing operations only, as these parameters are shown either to not be of known importance as attributed to barometric condensing operations (e.g. fecal coliforms), or are effectively controlled by use of other primary parameters (e.g., use of BOD_5 for control of related TSS).

Other parameters (COD, Total Coliforms, and Alkalinity) were not chosen because they represent alternate methods of estimating other general and more primary waste water parameters, as BOD_5 fecal coliforms and pH.

The parameter of ammonia and other nitrogen compounds is not selected as this waste water component will receive substantial and adequate reduction through barometric condenser water entrainment control and biological activity.

Total phosphorus and total dissolved solids (TDS) are not judged primary parameters for control at current concentration levels normally experienced at beet sugar processing plants. Furthermore, the cost factors and associated technical difficulties of further reduction of these constituents in large volumes of process waste water as experienced in the beet sugar processing industry preclude feasible application of available methods. The addition of lime within a recycling flume water system may be expected to reliably result in attendant reduction of phosphorus in the flume water through precipitation. Further phosphorus reduction would be unwarranted.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

Introduction

Current technology for the treatment and control of beet sugar processing wastes does not provide a single scheme that is completely applicable under all circumstances. The major treatment and disposal methods applicable to beet sugar processing wastes include reuse of wastes, coagulation, waste retention ponds or lagooning, and irrigation. The meaning of the above statement is that there is no known one treatment (biological, chemical, or physical) process which is universally applicable for complete pollution abatement for beet sugar processing wastes. Individual factors must be taken into consideration in adapting any one single plant to generally established guidelines.

In arid climates (California and Arizona) climatic conditions are favorable to permit no discharge of waste waters to navigable waters through land disposal. The waste waters are usually treated in waste stabilization lagoons for subsequent irrigation purposes or are contained in open earthen holding ponds where the waste water is eliminated by evaporation and soil filtration.

Detailed studies and previous efforts at various plants in the South Platte River Basin for treatment of beet sugar processing wastes (primarily through land spreading, aeration fields, and waste holding ponds) have generally proved to be ineffective in obtaining waste water effluents of suitable quality for discharge without detrimental effects on receiving streams. The problems resulted from the unadaptability to the regional climatic conditions, physical design limitations of installed units, and poor operating and maintenance practices.

Pollution loads of wastes have been reduced by better control of inplant practices; reuse of some wastes as process water; recirculation of flume, condenser and other waste waters; screening; settling; waste water retention; and waste treatment in waste stabilization ponds.

The proper design, operation, and maintenance of all waste treatment processes and pollution control facilities are considered essential to an effective waste management program. Awareness of the problem and priority recognition are necessary ingredients in an effective pollution control program. The 1971 Federal Water Pollution Control Administration's report of the beet sugar processing industry in the South Platte River Basin includes a discussion of recommended staffing patterns requisite to adequate waste water control and process management.

In-Plant Control Measures and Techniques

In-plant control measures are extremely important in the overall scheme for pollution control of beet sugar processing wastes. These measures include the proper handling of sugar beets before reaching the plant, design of beet flume systems to facilitate dry-handling techniques, process water reuse, dry methods for handling lime mud cake, conversion of Steffen filtrate to usable end-products, and the reuse and recovery of various flows in the beet sugar processing plant.

Handling of Sugar Beets

Although handling of the beets in the field and en route to the plant are not strictly part of in-plant operations, these procedures are directly related to the waste disposal problems at the plant and therefore warrant special attention. A major concern in handling of beets at the plant is the large quantities of soil brought into the plant with the incoming beets. The sugar processors, however, generally consider production factors, beet condition, and sugar content to be of greatest concern.

The soil and associated trash become part of the plant waste and may without proper control eventually enter the receiving watercourse. Increased mechanization on the farm, mechanical harvesting of the beets, and harvesting during wet soil conditions have led to increases in amounts of tare accumulated at plants. Some solid waste or tare is removed by shaking and screening before processing, and is returned to the beet delivery source. However, the large majority of delivered soil enters directly into the plant through the flume system.

To aid in waste abatement, a change in the method of harvesting and delivery of sugar beets to the plant is suggested. The removal of soil, leaves, and trash in the field would provide the plant with the cleanest possible raw product and tend to solve many present problems. Without adequate control measures, late season irrigation, and wet-field harvesting contribute to increased waste treatment needs and cost of settling devices in complete recycle flume water systems. Many, if not all, beet sugar processors possess sufficient influence to require that proper measures be taken to reduce soil in the fields. Dry tare removal techniques are highly desirable but may result in some undetermined increase in harvesting costs. However, if extensive plant waste treatment or retention facilities are to be relied upon for removing these solid materials, the results will undoubtedly be even more costly and less efficient.

Whereas storage of beets in northern climates is necessary because of the short growing season, storage of beets before processing is generally not practiced in California and southern climates of the U. S. There the beets are processed directly after shipment from the field. Storage of the beets in these areas for any length of time (days) results in a loss of sugar content of about 1 kg of sugar/kkg of beets sliced (2 lb/ton of beets sliced).

Deterioration of the sugar beets within storage can be minimized by maintaining proper conditions in the stockpiles and reducing storage time as much as possible. More care should be given to preventing damage and breakage of the beets. In this regard, the mechanical equipment and handling procedures for loading and unloading appear to suggest improvement needs. These measures are highly important for reducing pollution loads in the beet flume water.

A satisfactory method for storing beets for long periods has not yet become available for general use. The operation of the plants is therefore intermittent, and the sugar is extracted during a seasonal "campaign" of about 100 days duration mainly in the months of November through January in the greatest portion of the United States.

The Beet Fluming System

In recent years many plants have reduced their available beet storage facilities, shortened their fluming system, and integrated a truck delivery and a truck hopper installation on the processing line. Other plants have provided belt conveyors for transporting beets at least part way into the plant. Either minimum contact time between the sugar beets and the flume water or dry handling procedures serve to reduce the waste loads imposed upon the beet flume system. At least two plants have significantly reduced waste loads by this process (1).

From the standpoint of production, hydraulic fluming is an effective and expedient means of transporting and cleaning the beets and of thawing frozen beets in the extreme northern climates. One disadvantage of this technique is the loss of sugar to the flume waters. An additional pollution control measure is the complete dry handling of beets until they reach the washer. Beets may receive mechanical shaking or scrubbing for removing most of the dirt and solids followed by high pressure spray jets at the washing table. Dry handling, however, can be a serious disadvantage in colder climates where flume waters promote necessary warming and thawing of sugar beets. If hot exhaust gases and steam are generally available at the plant, they may possibly be adaptable for unthawing of beets before processing.

The typical flume water recycling system as is commonly used within the beet sugar processing industry, is judged a relatively inexpensive means of providing treatment for reuse and retention of flume water. Plants that recycle flume water have demonstrated that the suspended solids concentration of the waste is very amenable to gravity clarification, especially if lime is added. Land is required for the settling device and for the disposal of sludge removed from the clarification facilities.

Mechanical clarifiers are preferred to earthen holding ponds for the settling and clarification of flume water because of reduced land area requirements, increased efficiency of solids removal, and better control of the chemical and physical characteristics of the recycled flume water. Odors can generally be controlled to acceptable levels with the addition of lime to maintain alkaline conditions (pH above 10).

Reuse of Process Water

The reuse of process waste waters (pulp press water, pulp transport water, wet pulp screen waters) has been one of the better areas of waste source elimination by the industry. Process waters are reused for a variety of in-plant needs, although the general practice is to return them to the diffuser. The favorable economics in producing dry exhausted beet pulp for an established animal feed market and additional sugar recovery obtainable through reuse of process waters have contributed in large part to this change.

The continuous diffuser has replaced multiple diffusion cells and created flexibility in process water reuse by significantly reducing the volume of waste waters generated as a result of the diffuser system. A continuous diffuser consists of an inclined cylinder in which hot water flows downwards by gravity while the beet cossettes are moved in the opposite direction by means of paddles. These spent cossettes are discharged continuously at the upper end of the diffuser. Process water return to the continuous diffuser requires careful control and in some cases treatment. In addition to generally improving processing rate, use of continuous diffusers is also accompanied by increased sugar recovery gains.

Pulp transport water has been eliminated in many plants by a dry conveyor system which moves exhausted pulp to the presses. Return of pulp press water to the diffuser is a universally accepted practice today. The quantity of press water obtained varies with the efficiency of the pressing operation. The pulp press is effective in reducing the water content of the exhausted beet pulp from 95 percent as the pulp leaves the diffuser to 80 percent moisture from the presses.

Virtually the entire industry is now equippped with pulp drying facilities. The one remaining plant employing wet pulp disposal through use of a pulp silo (Torrington, Wyoming) is scheduled for replacement of the silo with a pulp drier by October, 1973. With installation of a pulp drier at this plant, pulp silo drainage water as a polluting source will have been completely eliminated. In addition to reducing a substantial waste disposal problem, pulp drying equipment can usually be justified economically. Dried pulp yields from a beet sugar plant average about 60 kg/kkg (120 lbs/ton) of beets processed. With molasses addition, the yield is about 75 kg/kkg (150 lb/ton). This pulp is generally sold as a source of livestock feed. The price of pulp varies on the competitive market with grains but was selling for about \$66/kkg (\$60/ton) for use as livestock feed in early 1973.

Handling of Lime Muds

Handling of lime mud wastes has been associated with problems of fermentation and noxious odors at many plants. The calcium carbonate sludges are generated from "juice" purification and other operations within the beet sugar processing plant. Lime mud cake is recovered from vacuum filters at approximately 50 percent moisture content. The usual practice consists of adding water to the lime mud cake, thereby producing a slurry which is easily transported by pumping to disposal locations.

Various techniques are presently in existence for the handling and reuse of lime mud slurry wastes. The general procedure is to dispose of the slurry through complete retention in an earthen holding pond. At the Manteca, California, plant the deposited lime mud cake is recovered from the pond and recalcinated for reuse within the process. A similar procedure is employed at the Mendota, California, plant, in which a portion of the lime mud slurry is dewatered and recovered through a centrifuge operation while the remaining lime mud slurry is contained in a holding pond. At the Arizona plant, lime mud is handled by a low water dilution/air pump conveyance for movement to holding facilities rather than by the conventional method of slurrying. Other plants project the use of similar conveyance facilities in the near future. A number of plants in Europe and Canada also employ dry means of conveyance and disposal.

All plants presently impound waste lime mud generally in separate holding ponds. The lime mud pond must be sufficiently large and the lime mud as concentrated as possible so that pond size, with normal evaporation and seepage, will permit complete containment. Lime mud pond discharge is an extremely strong waste, and discharge to receiving water bodies can not be permitted. In some plants excess lime mud pond water is recirculated to the fluming system. The industry commonly uses a single storage pond for lime mud, whereas European practice is to employ separate ponding of the settled solids and the supernatant.

Problems of fermentation and noxious odors have been associated with the long-term holding of lime mud wastes, but these can be minimized through utilization of shallow pond depths and/or aeration. Allowing accumulated lime mud to dry by containment in holding ponds is commonplace. The industry is presently experimenting with lime reclamation and reuse systems for recovery of the solid lime product. The lime mud may be recovered for use as a sweetener on acid soils. Studies have also been directed to the reuse of burnt lime residue within the plant and in the manufacture of cement and related products. The cost of these methods must be balanced against those of waste abatement and treatment costs that can be expected at the individual plant.

At one plant lime cake is dried in a kiln and pulverized, and optimum moisture content for land spreading is maintained at about 17 percent. A ton of lime mud filter cake may contain 3.2 kg (7 lb) organic nitrogen, 5.9 kg (13 lb) phosphoric acids, 0.91 kg (2 lb) potassium, and 200 kg (440 lb) organic matter (13).

Steffen Filtrate Conversion

Steffen filtrate generated in the Steffen process is generally converted to concentrated Steffen filtrate (CSF) and added to dried pulp as a component in animal feeds. An exception in one operation is that the Steffen waste is spread under controlled conditions within a 8.1 hectare (20 ac) holding pond for disposal.

Beet pulp with the addition of concentrated Steffen waste at most plants is presently sold for livestock feed at approximately $54/kkg ($60/ton) of pulp. However, the amount of concentrated Steffen filtrate which can be added to beet pulp for livestock feed is limited by the high ash content of the filtrate waste.

Barometric Condenser Waters

The beet sugar processing industry has demonstrated that waste water associated with the barometric condensing operation can be reused in the sugar manufacturing process. These waters may be used for diffuser makeup water, raw water supply, beet flume recirculation system makeup, lime mud slurrying, gas washing, and miscellaneous uses. Many such uses for condenser water are found at plants exhibiting extensive recycling and land disposal technology.

Entrainment of organic matter in condenser water requires careful control of the specific unit operation. However, entrainment separators on evaporators and vacuum pans are effective in greatly eliminating entrainment into condenser water. Most plants within the industry presently employ some type of entrainment control device. Condenser waters may be detrimental to the receiving water because of temperature reaching as high as 65°C (149°F) and the almost complete absence of dissolved oxygen.

Where adequate water supply is available, the condenser waters are seldom recycled. In some areas the waters are first passed through cooling devices and the pH level is controlled before subsequent disposition. Under normal operating conditions, the BOD_5 content of condenser waters may be as low as 15-30 mg/l. Under best operation, BOD_5 levels in barometric condenser waters may be controlled within the range of 10-15 mg/l. However, BOD_5 levels actually discharged to receiving waterbodies in excess of 100 mg/l have been documented. This was generally a result of careless operation and inadequate control procedures.

Treatment of condenser waters on a one-time use basis (without recycling) is not judged technically or economically feasible because of the large volume and relatively low pollutant concentrations. Cooling towers, open earthern ponds, or spray ponds may be used to permit recycling of condenser waters and minimize total plant water use. The highest degree of control is represented by recycling the condenser waters in a separate system. A dual closed-loop condenser water system was recently installed at one plant. One system is employed to supply heated water for fluming purposes; the other system serves to cool the condenser water for recycle for condensing purposes with makeup from fresh water sources.

In open recirculating systems the evaporation of water in cooling ponds or towers increases its dissolved solids concentration, while windage loss removes dissolved solids from the system (108). Evaporation loss generally accounts for about 1 percent for each drop in temperature of 5.6°C (10°F) through the pond or tower. Windage losses are 1.0 to 5.0 percent for spray ponds, 0.3 to 1.0 percent for atmospheric towers, and 0.1 to 0.3 percent for mechanical draft cooling towers. The mineral concentration can be held within desired limits by bleeding recirculating water from the system or by softening or demineralizing the make-up water. Slime and algal growths in condensers and heat exchangers may seriously impair their effective operation. Control of such growths is generally accomplished by the addition of cooling water chemicals such as chlorine that will either prevent the formation of growths or destroy existing growths. Chlorine may be added intermittently to the system in an amount that will produce an excess of several milligrams per liter of free available chlorine for a short period to prevent slime growths. The free chlorine is readily removed from the recirculated water through the evaporative cooling process for temperature reduction.

Water Use and Waste Water Management

Experience within the industry has shown that proper management, design, construction, operation, and maintenance of waste treatment and disposal facilities all contribute to an overall efficiency in plant operation.

A broad spectrum of water reuse and waste disposal practices exists in the beet sugar industry throughout individual plants in the U. S. and abroad. In-plant measures have proven more effective than end-of-process waste treatment in contributing to a successful waste management program.

In recent years the industry has recognized its responsibilities for pollution control and has begun programs to substantially reduce the pollution impact through improved waste management, design of facilities, reuse of waste water, flow reduction measures, and other pollution control devices.

Proper planning and design of treatment and control measures are a necessity. Structures which bypass treatment or disposal sites should be eliminated. Similar structures for bypassing treatment to land disposal or standby storage should be designed with positive reliable controls to serve only in emergency. The facilities must provide for intercepting various spills and unintentional waste discharges and returning these to the waste treatment or disposal system. Proper compaction and construction of waste treatment lagoons and holding ponds are necessary to afford satisfactory treatment and to properly control land disposal of process waste waters.

Once the waste control and treatment facilities are established, operation and maintenance of these facilities are most important. All devices and procedures intended for waste abatement should be considered as important as the process operations.

The importance of good administrative control and plant records must also be emphasized in relation to the waste water control program. Without proper administration, a program will suffer serious shortcomings. A logical division of responsibility and organized approach are necessary. A successful program requires that lines of authority and responsibility be fully delineated and that each person clearly understand his explicit responsibilities. A prescribed format of data gathering and recording is considered essential to a well-functioning pollution control program.

Treatment and Control Technology

Current Treatment and Control Practices Within the Industry

Classification of waste treatment and disposal techniques at the various beet sugar processing plants is difficult, since such practices range from little treatment to treatment, storage and land disposal of all wastes. Procedures for reduction of BOD_5 differ in principle. Some companies rely chiefly on anaerobic fermentation in deep holding ponds others on aerobic biodegradation in shallow ponds with or without mechanical aeration. Presently, a total of 11 beet sugar processing plants handle all waste waters through extensive in-plant recycling and reuse and complete land disposal of waste through holding ponds, stabilization lagoons, or by irrigation. In California, use is made of lagoon contents in many cases for irrigation of crops. No adverse effects on water quality are identifiable or attributable to this land application practice as the waste is completely disposed of on the land without ill effect. Plants presently accomplishing the level of technology resulting in zero discharge of waste water pollutants to navigable waters are located at Moses Lake, Washington; Hereford, Texas; Spreckels (Salinas), Betteravia, Manteca, Mendota, Tracy, Woodland and Hamilton City, California; Chandler, Arizona; and Goodland, Kansas.

In general, plants in the North Central portion of the United States (Montana, Wyoming, Nebraska, and Colorado) and in Michigan and Ohio have reported relatively higher amounts of BOD_5 per unit weight of beets sliced as discharged to streams. This generally is attributable to less favorable soil and climatic conditions for land disposal, location of plants near developed areas, and/or smaller and older plants generally located in these regions. Notable exceptions are the plants at Longmont, Eaton, and Brighton, Colorado. Present treatment and control practices characteristic of the industry are summarized in Table VIII entitled "Summary of Selected Pollution Control Practices at Beet Sugar Processing Plants." The practices summarized in Table VIII are applicable to individual beet sugar processing plants for handling and disposal of flume (beet transport) water and condenser water. These two waste sources are presently those of primary importance within the industry. Process waters (pulp press, beet transport, and pulp silo drainage) have been eliminated as a waste source by in-plant recycling or dry pulp transport. One plant still employs a silo for drainage of wet beet pulp. However, the silo is scheduled for replacement by October, 1973. All other plants employ pulp dryers for handling exhausted beet pulp. Lime mud is universally discharged to holding ponds without discharge to surface waters. Steffen waste (Steffen process only) is concentrated for addition to dried beet pulp or disposed of on land in isolated cases without discharge to surface waters. Miscellaneous waste waters (floor drainage, gas washer water, chemical wastes from cleaning of evaporators and crystallizers, etc.) are discharged to flume (beet transport) systems or disposed of by separate land disposal facilities without discharge to surface waters.

Treatment and control technologies applicable to various waste water components of the beet sugar processing plant are discussed below.

Flume Water - A preventive measure that can be developed at all plants for the reduction of the flume water waste volume is dry handling and transport of beets after they reach the plant. One plant presently has dry beet handling facilities for conveyance of beets into the plant. The water fluming system is substantially reduced to approximately 15 meters (50 ft) in length and the beets are washed under high-pressure sprays.

If dry fluming is not employed, the initial step in the treatment of flume water is the screening process to remove suspended solid organic material (beet fragments, etc.) which would otherwise settle in holding ponds as slowly decaying organic material. In a recirculating flume water system, clarification of the recirculated waste water flow is accomplished through the use of earthern holding ponds or mechanical clarifiers. The sludge removed from the settling facilities is generally discharged to a separate earthen holding pond for complete retention.

Table VIII
Summary of Selected Pollution Control Practices at Beet Sugar Processing Plants

						Existing Pollution Control Practices									
Beet Sugar Processing Plant	Beets Sliced	Metric tons/day	(Tons/day) ---	Molasses Worked Metric Tons/Day	(Tons/Day)	Discharge to Navigable Waters	Retention or Land Disposal for Flume Water	Maximum Flume Water Recycling	Partial Flume Water Recycling	Maximum Condenser Water Recycling or Re-use	Partial Condenser Water Recycling or Re-use	Land Disposal of Condenser Water	Discharge of Excess Waste Water to Municipal System	Treated Waste Water Used for Land Irrigation	Use of Cooling Devices for Condenser Water
Nampa, Idaho		[illegible]3	(9000)			Y	Y°	Y			Y	Y°	Y		
Moses Lake, Washington		710	(8500)	204	(225)	N	Y	Y		Y		Y			Y
Rupert, Idaho		0100	(6725)			Y'	Y°	Y			Y				Y
Nyssa, Oregon		5964	(6575)	185	(204)	Y	Y°	Y							
Hereford, Texas		5895	(6500)			N	Y	Y		Y		Y			
Brawley, California		5895	(6500)			Y'	Y°	Y		Y		Y°		Y	Y
Salinas, California		5895	(6500)	317	(350)	N	Y	Y		Y		Y		Y	Y
Drayton, North Dakota		4716	(5200)			Y'	Y°	Y			Y	Y°			Y
Betteravia, California		4535	(5000)			N	Y	Y		Y		Y		Y	Y
Twin Falls, Idaho		4376	(4825)	205	(226)	Y	Y°	Y		Y					Y
Moorhead, Minnesota		4172	(4600)			Y'	Y°	Y			Y	Y°		Y	Y
Idaho Falls, Idaho		3991	(4400)	113	(125)	Y'	Y	Y			Y				Y
Billings, Montana		3809	(4200)	163	(180)	Y	Y	Y							
Manteca, California		3809	(4200)			N	Y	Y		Y		Y		Y	Y
Chandler, Arizona		3809	(4200)			N	Y	Y		Y		Y		Y	Y
Mendota, California		3809	(4200)	200	(220)	N	Y	Y		Y		Y		Y	Y
Crookston, Minnesota		3628	(4000)			Y'	Y°	Y				Y°			Y
Tracy, California		3628	(4000)	102	(123)	N	Y	Y			Y	Y		Y	Y
Toppenish, Washington		3464	(3825)			Y	Y	Y			Y				
Bay City, Michigan		3447	(3800)			Y	Y°		Y						
Woodland, California		3265	(3600)	103	(180)	N	Y		Y	Y		Y			Y
Sidney, Montana		3174	(3500)			Y'	Y°		Y			Y°		Y	Y'
Ft. Morgan, Colorado		3174	(3500)	167	(187)	Y	Y	Y							
Loveland, Colorado		3174	(3500)	172	(190)	Y	Y	Y				Y°			Y
Fremont, Ohio		3083	(3400)			Y	Y°	Y		Y		Y°	Y		Y
Rocky Ford, Colorado		3083	(3400)	85	(94)	Y	Y	Y			Y			Y	
Longmont, Colorado		2902	(3200)	171	(189)	Y'	Y	Y				Y°		Y	
Scottsbluff, Nebraska		2902	(3200)	59	(175)	Y	Y	Y				Y°			Y
Torrington, Wyoming		2902	(3200)	126	(139)	Y'	Y	Y			Y	Y°			
Goodland, Kansas		2902	(3200)			N	Y	Y		Y		Y			Y
Clarksburg, California		2721	(3000)			Y	Y	Y			Y			Y	
E. Grand Forks, Minnesota		2630	(2900)			Y'	Y°	Y		Y	Y°				Y
Ovid, Colorado		2542	(2800)			Y	Y	Y							
Garland, Utah		2449	(2700)	100	(110)	Y	Y	Y						Y	
Hamilton City, California		2267	(2500)			N	Y	Y		Y		Y			Y
Sterling, Colorado		2177	(2400)			Y	Y°		Y						
Bayard, Nebraska		2041	(2250)			Y	Y	Y							
Mitchell, Nebraska		2041	(2250)			Y'	Y°					Y°			
Brighton, Colorado		1995	(2200)			Y	Y	Y			Y	Y°			Y
Eaton, Colorado		1995	(2200)			Y	Y	Y			Y	Y°			Y
Greeley, Colorado		1995	(2200)			Y	Y	Y			Y	Y°		Y	Y
Lovell, Wyoming		1995	(2200)			Y	Y	Y				Y°			Y
Gering, Nebraska		1995	(2200)	91	(100)	Y	Y	Y							
Sebewaing, Michigan		1905	(2100)			Y	Y°		Y		Y				
Carrollton, Michigan		1814	(2000)			Y	Y°	Y							
Caro , Michigan		1814	(2000)			Y	Y°	Y			Y	Y°			Y
Worland, Wyoming		1746	(1800)	69	(76)	Y	Y	Y			Y				Y
Delta, Colorado		1633	(1800)	54	(60)	Y	Y	Y			Y	Y°			
Santa Ana, California		1633	(1800)	87	(96)	Y	Y°			Y		Y°	Y		Y
Findlay, Ohio		1406	(1650)			Y	Y°	Y		Y		Y°	Y		Y
Ottawa, Ohio		1451	(1600)			Y	Y°	Y		Y		Y°	Y		Y
Croswell, Michigan		1270	(1400)			Y	Y°				Y	Y°			Y

' Occasional discharge only
° Partial

Y = Yes
N = No

The beet sugar processing industry has demonstrated that a drawoff or blowdown rate of 20 percent of the total water flow is sufficient to maintain suspended solids control and total dissolved solids concentration at or below approximately 10,000 mg/l. Such a level of total dissolved solids concentration and suspended solids control in a fluming system will not promote, under the prevailing pH conditions, abnormal scaling of the piping in the waste water conveyance system.

The pH of flume water is a highly variable and erratic factor requiring careful control by the addition of lime. Proper control can be accomplished through pH determinations on grab samples of flume water taken at least every two hours as is the practice at some plants. At a number of other plants, milk of lime is added to the flume water as it leaves the screens or as it enters settling ponds or clarifier facilities. This lime addition serves to keep the pH at a level which impedes bacterial action, thereby reducing odors and corrosive effects. Lime addition also assists in sedimentation as a flocculating agent.

The amount of soil associated with incoming beets varies with the wetness or dryness of the harvesting season, soil type, and location. A plant slicing 363,000 kkgs (400,000 tons) of beets during a campaign may accumulate 5,100 to 6,130 cu m (20 to 24 thousand cu yd) of soil in its settling ponds. At one plant 40,500 cu m (53,000 cu yd) of dirt were removed from lagoons in 1969 after processing 903,000 kkgs (995,000 tons) of sugar beets.

Barometric Condenser Water - Condenser water is characterized by:

1) Relatively high temperature 55-65°C (131-149°F)
2) Entrained organics from boiler vapor entrainment
3) Alkaline properties

The pH varies between 8 and 10 but usually is less than 9 and results from entrainment of ammonia during the raw juice evaporation process. Reuse of condenser water is a common industry practice. Many plants make some in-plant reuse of condenser water and discharge the excess to water bodies. A total of 11 plants presently accomplish complete land retention of condenser waters without discharge to surface waters; twenty-three plants practice partial land disposal of condenser waters; while 18 practice no land disposal for this waste component. Thirty-five plants practice maximum or partial recycle of condenser water. Cooling of condenser water before discharge to receiving streams, or recycling, is usually necessary for protection of the quality of receiving waters. A total of 32 plants employ cooling devices.

Surface or non-contact condensers offer a possible means of non-contaminant use of condenser waters in lieu of entrainment control devices with conventional barometric condensers. Surface condensers provide positive control against contamination of condenser water through non-contact between vapors to be condensed and cooling water. The alternative method of control is relatively expensive (estimated at roughly $200,000 for the average- sized beet sugar processing plant) and requires larger water volumes than barometric condensers. The method is reliable as a mechanism of pollution control, and is worthy of consideration at new beet sugar processing plants planned for construction.

When using cooling towers for condenser water cooling and recirculation, it has often been found economical and expedient to supplement the recycled condenser water with cool fresh water from wells in order to reduce the temperature of the recycled water. Where employed, such practices often do not result in conservation of water since larger water volumes are used than those needed to meet minimal barometric condenser requirements. In the Central and North Central portions of the United States additional cooling requirements for molasses in Steffen operations is obtained through use of large volumes of water from existing surface or ground water sources. At other locations, e.g., in California, heat exchangers are commonly employed to meet additional cooling requirements of the Steffen process.

In recycling systems cooling may be accomplished with spray ponds, cooling towers, evaporative condensers, and air-cooled heat exchangers. All but the last depend on the cooling effect of evaporation. The effectiveness of an evaporative cooling system is determined by the wet bulb temperature of the environment since this is the absolute lower limit to which the water can be cooled by evaporation. The actual terminal temperature may range from a degree or two below atmospheric temperature at high humidity (as measured in Fahrenheit) to 17°C (30°F) or more below atmospheric temperature when the air is very dry (88). Therefore, evaporative coolers are most effective in arid regions. As a rule of thumb, cooling towers are capable of lowering temperatures on a once-through basis to within 12°C (22°F) of wet bulb temperature.

Forced-draft cooling towers with bottom fans and countercurrent air flow are gaining favor over induced draft (top fan) and natural draft types for cooling heated waste waters. Cooling towers are generally more efficient than spray ponds for waste water cooling because of increased contact in the cooling tower between the heated water and circulating air.

Barometric condenser water resulting from beet sugar processing plants characteristically exhibits relatively high nitrogen content, attributed largely to ammonia (3 to 15 mg/l NH_3 as nitrogen) introduced by juice evaporating and sugar crystallizing operations. Therefore, the removal of nitrogen centers on the removal of ammonia-nitrogen.

Pilot plant experiments by Lof et. al. support the ability of air stripping to remove nitrogen from beet sugar plant condenser water effluent. Data for ammonia removal from a synthetic medium (prepared by the addition of NH_4Cl, $NaNO_3$ and $NaNO_2$ to tap water) indicate that most of the NH_3, removal in cooling tower operations occurs by air stripping rather than by oxidation to nitrite nitrogen. Removal of ammonia nitrogen at the 16 to 18 mg/l as N range was shown to be 25 to 50 percent over a 24-hour interval (6.2 passes through the cooling tower) for G/L weight ratios of 0.3 and 0.6, respectively. The G/L weight ratio equals the weight rate ratio of air to water, e.g., kg (lb) of air per hr. divided by kg (lb) of water per hr.

Applications of combined cooling and bio-treatment of waste waters have been utilized by means of cooling towers for refinery, corn milling operations, and bleached board production plants. Among other constituents, cooling devices sometimes with the addition of synthetic packing have been demonstrated effective in reducing temperature, sulfides, chemical oxygen demand, biochemical oxygen demand, and ammonia in this double duty role. BOD_5 and COD removals vary between 30 and 90 percent. Although heavy sliming occurred in several of the above cooling units, growth was reported not to be sufficient to cause any problem in cooling tower operation. Similar successful experiences with biological oxidation of pollutants are known to occur with efficient temperature reduction through use of aeration ponds, primarily at pulp and paper mills (6). BOD_5 reductions ranged from 80 to 95 percent. Aerobic treatment processes have been demonstrated effective in removing up to about 70 percent of total nitrogen in waste water (101).

The air-to-water ratio required in cooling barometric condenser waters by cooling devices at beet sugar processing plants may be estimated on the basis of the following thermodynamic considerations. Assuming ambient air with an absolute humidity of 0.011 kg (lb) water vapor per kg (lb) of dry air (75 percent relative humidity and 21°C (70°F) dry bulb temperature), adiabatic cooling, and air leaving the cooling device saturated with water, exit conditions of air after use for cooling would have an absolute humidity of 0.012 kg (lb) water vapor per kg (lb) dry air under exit conditions of 18°C (64°F) dry bulb temperature and 100 percent relative humidity. Therefore, under the assumptions, 0.001 kg (lb) water vapor per kg (lb) of dry air would be added to the air during the evaporative cooling process. In reducing the barometric condenser water temperature from 60°C to 20°C (140°F to 68°F), a total temperature decrease of 40°C (72°F) has occurred. With approximately 555 kg cal/kg (1000 BTU/lb) as the heat of evaporation of water and an estimated 40 kg cal/kg (72 BTU/lb) of water recirculated, evaporation to accomplish the required temperature drop would be estimated at 0.072 kg (lb) of water evaporated for each kg (lb) of water recirculated. Therefore, dry air requirements for evaporative cooling to accomplish the designated temperature decrease would be 72/0.012 x (1000) = 6 kg (lb) dry air/kg (lb) water recirculated.

Ammonia stripping as a treatment process has been demonstrated to be pH dependent, the optimum ammonia removal by stripping occurring at a pH of approximately 11. Studies conducted at the University of Wisconsin and elsewhere have substantiated high removal of ammonia (78 to 92 percent) by stripping at air/liquid loadings of 3345 l/l (447 cu ft / gal) and 4100 l/l (549 cu ft/gal), respectively.

The above discussion supports the conclusion that ammonia can be substantially removed from waste waters through appropriate cooling devices and aerobic waste treatment systems.

Ammonia is soluble in water and would be expected to be found in minimal concentrations under natural conditions. At atmospheric conditions, the solubility of ammonia in water is 0.89 mg/l, 0.53 mg/l, 0.33 mg/l, and 0.07 mg/l at 0°C (0°F), 20°C (68°F), 40°C (104°F), and 100°C (212°F), respectively.

Lime Mud Wastes - Plants normally release lime mud in the form of a slurry which is contained in holding ponds.

Two plants now reburn lime mud cake for the production of lime. One recent lime mud cake reburning operation has been discontinued, reportedly because of objections to dust emitted from the rotary kiln and cost inefficiencies. Lime mud cake from this operation is now being shipped to another factory for reburning.

Dry handling of lime mud cake is accomplished at a number of plants. One plant indicates plans to install dry conveyance facilities for lime mud cake during 1973. By using a dry conveyance system, the lime mud cake is transported to the disposal area without the conventional addition of slurrying water in order to permit pumping. Injection of compressed air at 0.7 to 1.1 kg per sq cm (10 to 15 psi) to maintain fluidity of the semi-liquified mass has also been an effective method of transport at the Chandler, Arizona plant.

Sale of lime mud cake for agricultural and other uses has not been notably successful. At only two plants, one in California and one in Washington, has any considerable outside use been made of the material. The rather large store of lime mud cake in California is being sold to farmers for use on peat soils at a somewhat faster rate than it is being produced. In Washington, a commercial distributor collects lime mud cake from the dry ponds for sale at 55¢/kkg (50¢/ton) for use in areas with acid soils.

A typical beet sugar processing plant employs one or more lime mud ponds, varying in depth from 0.6 to 3.0 m (2 to 10 ft). On occasion, miscellaneous wastes may be added to the lime mud ponds. Deposits from a given campaign are scraped from the pond bottom and added onto the dike walls. Where large ponds are employed, solids removal is not necessary for a period of many years. Active fermentation within the ponds may begin near the end of campaign in the central United States and is accelerated by the warmer temperatures occuring through spring and summer (13). Cleaning of lime mud ponds is a continuing, expensive chore at many plants. As a general practice, two or more lime mud ponds are available at a plant, enabling the operators to take one of the ponds out of service as required to permit removal of accumulated solid material.

The various difficulties in storing lime mud slurry, such as the viscous nature of the waste, land and construction costs, and possible offensive odors offer strong reasons for converting to a dry system of handling and disposal in most cases.

Steffen Waste - Steffen plants produce a liquid waste which has a high alkalinity as well as a high BOD5 and organic matter content. The solids content of the waste resulting from the Steffen process, in addition to the lime content, consist of the sugar and the nonsugars of the original molasses. The Steffen waste includes various inorganics together with a variety of organic and nitrogenous compounds.

When Steffen waste biologically degrades it soon loses its alkaline nature and various malodorous compounds are formed. Where this waste is disposed of in ponds, odor problems have become acute.

Because of the large variety of materials contained in Steffen wastes, it has been given considerable study as a potential source of byproducts. During World War I, a number of beet sugar plants concentrated the Steffen waste and burned the concentrate to produce a crude potash salt for fertilizer. Later, a successful process was developed to produce monosodium glutamate (MSG) from the concentrated Steffen filtrate (CSF). Feeding and nutritional studies have shown that CSF can partially replace molasses as a cattle feed supplement. This use has been the primary outlet for this material, since the attractiveness for sale of MSG has decreased. When used as a dried-pulp additive, CSF is normally limited in livestock feed by the solids (ash) content. Experience has shown that only about 30% molasses by weight, may be added to dried pulp for cattle feed.

Land spreading is another alternative method of disposal of Steffen waste. This can be accomplished with a minimum of odor production if managed properly. The dilute Steffen waste is spread in a thin layer over a land area which is quite level and divided into small parcels by low levees. This permits feeding the waste onto these parcels in sequence to allow absorption and drying before further additions. It is beneficial to disc or till the soil between campaigns to enhance its absorptive capacity. Such land spreading of Steffen waste with protection from runoff is practiced at the beet sugar processing plant at Salinas, California.

A study on a laboratory scale (68) demonstrated that Steffen waste can be treated with various yeasts, algae, and bacteria to produce a potential feed stuff while stabilizing the waste. But another study incorporating a four-pond system, was judged high in installation and operating cost without subsequent production of a usable byproduct.

To reduce the cost of evaporating Steffen filtrate, considerable effort is made to keep the concentration of the waste as high as possible without adversely affecting the purity of the saccharate produced. One method used is the return of cold saccharate filtrate as part of the dilution water. The volume of Steffen waste is thus reduced from about 42 l/kkg (10 gal of waste/ton) of molasses to about 25 l/kkg (6 gal of waste/ton).

General Wastes - General waste including floor and equipment, wash waters, filter cloth wash, and miscellaneous effluents are usually discharged to the general or flume water ponds.

Demonstrated and Potential Treatment and Control Technologies

General - Biological treatment of beet sugar processing waste has been effectively demonstrated. Two approaches to biological waste treatment are currently being used. They are anaerobic fermentation and aerobic oxidation. The former is believed to be the most efficient, resulting in the most nearly completely stabilized effluent. Anaerobic action does give rise to objectionable odors including particularly the odor of hydrogen sulfide. At some plants, neighboring residents have protested the annual nuisance of odors of anaerobic conditions.

The removal efficiencies of waste treatment processes are difficult to assess. Adequate BOD5 determinations are infrequently available in statistically significant numbers. Exceptions to this are the results of the intensive studies made by the EPA on the matter of pollution in the South Platte River Basin, and the various studies of experimental units conducted by companies or by the Beet Sugar Development Foundation. Past studies indicate that substantial BOD 5 reduction of beet sugar processing wastes can be accomplished by biological oxidation.

Common to all processes available for biological treatment of beet sugar plant wastes are the requirements for adequate screening of wastes to remove fragments of beets and other organic matter and facilities (mechanical or other) for separation of muds. Previous methods of handling the clarified or partly clarified liquid wastes were the following: 1) Direct discharge to streams during periods of high water flows; 2) anaerobic biological treatment in deep ponds, followed usually by aerobic action in shallow ponds or ponds equipped with mechanical aerators; and 3) aerobic treatment or ponds equipped with mechanical aerators; and 3) aerobic treatment alone.

Many studies have been performed on the treatment of beet sugar processing wastes utilizing biological means, including activated sludge, trickling filters, waste stabilization lagoons, and other methods (11). In many cases, comfirmative results have been obtained well beyond the pilot-plant stage.

Even though numerous methods of treatment of the various wastes from beet sugar processing plants have been applied with the object of producing an effluent suitable for discharge to surface waters, these methods are generally undesirable in comparison with inplant waste water reuse and recycling practices. Applicable treatment methods in the conventional sense present operational and economic questions as applied to large volumes of liquid produced during essentially a three-month period of the year generally known as the beet sugar campaign. Large treatment plant facilities would be required to handle the large waste volumes during a relatively short seasonal operation. If such conventional biological treatment systems are to be utilized effectively, waste water would have to be stored in large storage facilities to help sustain organic and hydraulic loading for the treatment facilities on essentially a year-round basis.

Inplant process control with reuse of waste waters rather than treatment and discharge has been generally adopted by the industry as an expedient and economical approach to pollution control from beet sugar processing operations. Various waste treatment and control methods applicable to beet sugar processing plants are discussed below.

Coarse Solid Collectors - Trash collectors, traps, and other recovery devices are normally placed at all major waste collection points within the plants. Proper design, installation, and maintenance of these devices are essential for adequate performance. Solids control is necessary not only for routine waste but also for spills, leakage, and inadvertent releases to the floor drains.

Fine-Mesh Screening - The screening operation is a preliminary step in waste treatment intended to reduce waste loads placed upon subsequent treatment and control units. For screening of flume water, inclined vibrating screens are generally preferred by the industry because they are more effective and less costly than other screening devices. Adequate screening of the waste flows from a typical plant may remove from 9 to 36 kkg (10 to 40 tons) of coarse wet solids daily. The recovered screenings are shredded and introduced into the pressed pulp and fed to the dryer. Screenings removed from recycled flume water are also generally fed to livestock with or without drying.

One plant provides dual vibrating screens which have 0.32 by 1.59 cm (1/8 by 5/8 in) slotted openings as the first unit within its flume water recirculation system. The screens remove about 29.7 kkg (27 tons) of wet solids daily, which are sold directly to local farmers for use as stock feed. Another operation employs three vibrating screens installed in parallel; the screens are preceded by a liquid cyclone or hydroseparator for removal of heavy grit and solids.

Grit and Solids Removal - Mechanical clarifiers or earthen settling ponds preceeded by coarse screening are generally used in recycle flume water systems. Mechanical settling units are usually preferred in the industry. The objective is to remove as much dirt, soil and other solids as possible. The large quantities of accumulated dirt and debris are deposited into sludge storage ponds.

Both earthen ponds and mechanical clarifiers can cause serious problems without proper operation, maintenance, and control but the mechanical clarifier merits careful attention. It is important that sludge underflows and flotable scum and grease be removed quickly, preferably continuously. If waste detention times are excessive, organic fermentation may occur in the settling facilities, resulting in organic acid and hydrogen sulfide buildup. Chlorination or pH control with lime addition may be used to retard such odor-producing action. In any case, efficient course screening ahead of the settling tank is essential. Indications are that clarifiers with detention times from 30 minutes to several hours will produce effective solids removal with minimum odors. With continuous flume water recirculation, dissolved organic material may increase to rather high levels (approximately 10,000 mg/l), necessitating blowdown and water makeup in the system for solids and scaling control.

Current state-of-the-art practices for mechanical clarifiers of wastes with settleable solids of 30 to 125 mg/l result in waters containing 0.3 to 1.0 mg/l of settleable material. Fine clay particles which do not readily settle must be removed by chemical flocculation in the pH range of 10.5 to 11.5. Addition of lime not only retards fermentation but serves to raise the pH to the level necessary for effective flocculation.

Waste Holding Ponds - Waste holding ponds have widespread use in the beet sugar processing industry. Their function is similar to that provided by mechanical settling. Less care is generally given to their design, operation, and maintenance as mechanical settling devices. The pond facilities normally serve for retention of wastes as contrasted to treatment benefits for which a waste stabilization lagoon is designed. Waste water detention times in earthen holding ponds generally range from 24 to 48 hours. Minimum detention times are encouraged for minimizing noxious odors associated with organic fermentation when ponds are used for solids settling. Holding ponds, as distinguished from waste stabilization lagoons, serve for solids removal, short-term retention, or long-term storage without discharge to surface waters. In the case (long-term storage) the waste water is disposed of by evaporation and filtration. Waste stabilization ponds on the other hand are specifically designed and constructed to provide waste treatment for subsequent controlled land disposal, irrigation, or discharge to surface waters.

Jensen states that the pond system, using single or multiple basins, has been the most common means of solids removal for beet sugar processing waste waters. He recommends that the system be shallow and flowing in order to avoid the odor nuisances of hydrogen sulfide gas generation. From his experience, Henry favored settling ponds for reasons of economy and also suggested the following principles in relation to these ponds. First, the waste water should enter the settling pond with minimum velocity and circulate evenly but quickly without interference with settling. Second, the use of large ponds is advisable in order to minimize dike construction. Third, pond bottoms should be level, and grass and weeds should be removed from the bottom and sides frequently. Other studies, conducted in Great Britain, have indicated that the ideal shape for a settling pond may be a rectangle five to six times as long as wide, providing a flow-through velocity of about 0.24 m/min (0.8 ft/ min). The British investigations also suggested that small ponds were advantageous in the event of dike rupture, since less waste material would accidently enter the receiving stream.

Experience within the industry has indicated that odor problems accompanying the long-term retention of waste waters in earthen ponds at many plants can be minimized by the maintenance of shallow pond depths (optimum of 45.7 cm or 18 in). In the U. S., shallow lagoons are preferred to deep ponds for municipal waste, and operating depths are generally in the range of 0.92 to 1.53 m (3 to 5 ft) However, effective settling depths will range from less than 0.3 m (1 ft) to 6.1 m (20 ft). In actual practice the holding ponds may fill rapidly with solids.

In the construction and operation of holding ponds, sealing of pond bottoms to eliminate or control percolation to acceptable maximum rates may be necessary even though a mat of solid organic material often provides some degree of self-sealing. The general criterion, adopted by many State pollution control agencies for waste stabilization lagoons for municipal wastes, is a 0.635 cm (1/4 in) maximum drop in pond liquid depth each day. This has general application to waste holding ponds as a practical limit of filtration and should not be exceeded. In some instances, state pollution control agencies may desire or regulate maximum allowable soil filtration from waste holding or treatment ponds to less than 0.635 cm (1/4 in) per day. In these cases, lower soil filtration rates are applicable. No contamination of ground water must result from controlled soil filtration. Holding ponds in use in the industry today have no specific provision for filtration control. Even with uncontrolled soil filtration of waste water, no pollution of ground waters has been positively attributed to date to land application practices.

A number of process waste water storage, retention, or land disposal systems have been investigated, some systems proving to be of little or no protection against polluted discharges. In this regard, two types of long-term waste ponding have been generally in use: (1) Waste retention with controlled regulated intermittent discharge of holding pond contents to surface receiving waters and (2) long-term waste storage and disposal with no discharge of process waste waters to navigable waters. The procedure of controlled discharge from holding facilities to receiving waters is practiced at the Moorhead, Crookston, and East Grand Forks, Minnesota, beet sugar processing plants and at the Drayton, North Dakota, plant. In this region, waste flows are contained in holding ponds during the processing season and the contents are discharged under controlled conditions to receiving waters during the spring high stream flow period. Some reduction in BOD$_5$ content of the ponded waste takes place during the winter storage period and before regulated discharge to the river, but the BOD reduction is usually not great.

The first extensive study of long-term waste storage was conducted at the Moorhead, Minnesota, plant during the 1949-1951 campaigns. Waste flume waters, together with pulp press waters, were released into two 3.7 meter (12 ft) ponds identical in capacity, with a total area of 33 hectares (82 ac) and a total volume of 1340 million liters (354 million gal). A third lagoon, 0.9 meters (3 ft) deep, covering 20 hectares (50 ac) and providing 190 million liters (50 million gal) capacity, was maintained in reserve until late in the campaign. The total campaign used 1600 million liters water volume (423 million gal) in 1950. Uncontrolled discharge from the ponds began in early spring following severe winter conditions and much ice cover over the ponds.

The study showed that waste treatment during the campaign itself was effected largely by settling of suspended matter within the ponds. Over this period BOD$_5$ reductions ranged from 48 to 58 percent and suspended solids removal was indicated at about 97 percent. After the processing campaign ended, the stored waste waters underwent no further decrease in BOD$_5$ reduction. This was attributed to complete cessation of biological activity within the ponds because of freezing and possible lack of secondary nutrients. The study concluded that long-term waste storage even in cold climates, would provide effective removal of suspended solids but would be effective in removing only one-half of the BOD$_5$ load.

A later study undertaken in 1964-1965 in the Red River of the North included the Moorhead, East Grand Forks, and Crookston, Minnesota plants. Discharge was controlled according to the amount of flow, dissolved oxygen, and BOD$_5$ in the receiving stream, and was permitted before and following ice cover on the river. The results of the study showed that the Moorhead pond effluent contained 449 mg/l BOD$_5$ and 163 mg/l total suspended solids and had median values of 1.5 million total coliform bacteria and 1.25 million fecal coliform bacteria per 100 ml. The discharge at the East Grand Forks, N. D., plant had effluent values of 164 mg/l BOD5, 54 mg/l total suspended solids, 22,100 total coliforms per 100 ml, and 1,720 fecal coliforms per 100 ml. Waste removal efficiencies were not determined.

Land Spreading of Wastes or Aeration Fields - The term aeration fields is applied to the process of spreading wastes from beet sugar processing plants over large land surfaces. The wastes infiltrate the ground in numerous, shallow channels, and are collected and disposed of at the opposite end of the field.

The history of aeration fields for beet sugar processing waste in the U. S. start, with studies conducted at the Loveland, Colorado, plant in 1951. The aeration field there covered 54 ha (133 ac). Suspended solids and alkalinity removals were reasonably good, but organic loads (BOD5) were reduced only to a minumum degree. The facility provided less than equivalent primary treatment, and waste concentrations in the final effluents remained at high levels. The merits of maintaining this type of extensive treatment area were seriously questioned in view of the results obtained.

A similar aeration field that was formerly used at Windsor, Colorado, was found even less effective than Loveland, producing less than 10 percent removal of BOD5, 60 percent removal of COD, and 60 percent reduction of TSS. The waste water entering the Cache La Poudre River contained approximately 1100 mg/l BOD5, 1060 mg/l TSS, and 6.6 million total coliform bacteria per 100 ml.

Full scale aeration field facilities were also constructed at a Nebraska plant during 1952, and evaluation studies were carried out over the 1952-1953 campaign. The total combined plant wastes were delivered to a 1,069 by 534 meter (3,500 by 1,750 ft) area of fairly level contour. Although native buffalo grass was present, only part of the field was described as a grassland filter as compared to installations in Europe. Waste channeling was quite evident and only 50 percent of the waste volume disappeared by downward soil percolation before reaching the end of the field. The 1952-1953 survey results showed that incoming waste levels of 482 mg/l BOD5 were reduced to 158 mg/l in the aeration field or that 67 percent BOD5 removal occurred. Corresponding values of total suspended solids were 5,125 mg/l and 63 mg/l, giving 99 percent apparent total suspended solids reduction. Similarly, total coliform bacteria numbers were reduced 89 percent. Although algal and fungal growths were abundant, the dissolved oxygen was quite low in the field. Average waste detention approximated 14 hours, and the results indicated that odor production was at a minimum. The aeration field is no longer in use.

Aeration fields were also used during the 1963-1964 campaign at three Colorado plants. It was observed that these treatment facilities did not embody many of the favorable characteristics of the earlier installation, and the aeration fields were beset with numerous operational and maintenance problems. The 1968 South Platte River Basin studies concluded that aeration fields, as they were maintained, could not by any means satisfy the water quality criteria recommended for the receiving waterbody. Further conclusions were that aeration fields support little or no vegetative growth, and because of short circuiting the wastes were often applied vegetative growth, and because of short circuiting the wastes were often applied only over a small portion of the field. Although the majority of suspended solids were removed, there is little or no other apparent benefit from the use of aeration fields for beet sugar processing waste.

Waste Stabilization Ponds or Lagoons - Waste stabilization ponds or lagoons are distinguished from waste holding ponds in that the former are designed, constructed, operated, and maintained in accordance with established design criteria and procedures for the primary purpose of effecting waste treatment for pollutant reduction. Waste holding ponds, while affording some benefit of waste treatment, serve primarily to store or retain the waste with or without discharge of pond contents to surface waters.

Many of the plants in California utilize waste stabilization lagoons for treatment of excess flume and condenser system waste waters. The impetus to provide treatment of waste waters has resulted from the advantages obtained by utilizing the treated waste waters for cropland irrigation in water-short regions. The installations are characterized by the use of many interconnected ponds generally in series, specifically designed for settling, biological oxidation, evaporation, and filtration. The various lagoons range generally from 0.6 to 3.0 meters (2.0 to 10 ft) in depth, with surface areas up to 80 ha (197 ac). The shallow ponds are aerobic, whereas the deeper basins were designed for controlled anaerobic digestion. The BOD_5 of the waters pumped from the final aerobic pond in series for irrigation is relatively low, of approximately 105 to 190 mg/l or less. The suspended nature of the BOD_5 is demonstrated by the fact that studies show that the BOD_5 of the pond effluent may be reduced to 7 to 10 mg/l by effective filtration. Essentially complete removal of total suspended solids by filtration is obtained.

Anaerobic-aerobic lagoons have been utilized on a pilot study basis for treating beet sugar processing wastes with encouraging results (65). Encouraged by the successful application of these principles in the treatment of other wastes, the Beet Sugar Development Foundation with funding support from EPA initiated a pilot plant study in California. The major objectives of the study were to demonstrate the waste removal efficiencies of the system and to determine methods to minimize odor in connection with this means of treatment. The system was evaluated with respect to the effects of varying feed rates and recirculation ratios upon organic waste removal, and the degree of odor control and microbial growth associated with the operations.

Hopkins et. al. found that if total beet sugar processing wastes were discharged uniformly across the upper end of 2 ha (5 ac) shallow lagoons with a detention time of about one day virtually all suspended solids, 55 percent of the concentration of BOD$_5$, and 63 percent of the weight of BOD$_5$ were removed. This procedure also reduced the alkalinity by 69 percent, completely eliminated nitrate nitrogen, and reduced ammonia nitrogen by 94.3 percent. Coliform bacteria increased, but phosphates were unchanged. Water loss was 4,040 cu m (3.27 ac ft) per day of which 222 cu m (0.18 ac ft) was due to evaporation and 3818 cu m (3.09 ac ft) was attributed to soil filtration.

At the California pilot plant, screened, settled plant waste water (principally flume water) was treated in a series of three ponds. These consisted of a 4.6 m (15 ft) deep anaerobic pond, a facultative pond 2.1 m (7 ft) deep, and an aerobic pond 0.9 m (3.0 ft) deep, from which the effluent could be discharged and also recycled to the anaerobic pond. Detention times varied from about 10 to 25 days in the anaerobic pond, 10 to 30 days in the faculative pond, and 10 to 20 days in the aerobic pond. Over the first two years of the study, the anaerobic, faculative and aerobic ponds were used respectively as the first, second, and third units in series. During September and October, 1966, influent BOD$_5$ values generally ranged from 1,200 to 1,650 mg/l. In the first experimental run, the applied organic loadings were 1383 kg BOD$_5$/ha/day (1,235 lbs BOD$_5$/ac/day) for the anaerobic pond, 931 kg BOD$_5$/ha/day (831 lbs BOD$_5$/ac/day) for the faculative pond, and 739 kg BOD$_5$/ha/day (660 lbs BOD$_5$/ac/day) for the aerobic pond. The results of the first run represented an overall waste detention period of about 35 days and provided 70 percent BOD$_5$ removal and 38 percent COD removal. The BOD$_5$ concentrations from inflow to outflow were reduced from approximately 1,200 mg/l to 350 mg/l. Another test, where there was no recirculation and the applied loadings were 1838 kg BOD$_5$/ha/day (1,640 lb BOD$_5$/ac/day) for the anaerobic pond, 502 kg BOD$_5$/ha/day (448 lbs BOD$_5$/ac/day) for the faculative pond, and 355 kg BOD$_5$/ha/day (317 lbs BOD$_5$/ac/day for the aerobic pond, with overall waste retention time of 70 days, provided approximately 90 per cent BOD$_5$ removal and 77 percent COD removal. Correspondingly, the BOD$_5$ concentrations were reduced from about 1,650 mg/l to 170 mg/l. These studies included the enumeration of algae, coliform, and fecal streptococci bacteria present within the system. Efficient removals were achieved with respect to both coliforms and fecal streptococci organisms, reaching 99.99 percent reduction in practically all cases. Although mechanical and other disturbances resulted in less than desirable treatment operation, the system indicated that beet sugar processing wastes could be successfully treated by such a system. BOD$_5$ and COD were effectively removed in the pond system with the highest removal rates occurring in the heavily organically loaded anaerobic pond. As long as algae were present in the aerobic pond, recycling of waste water from the aerobic pond to the anaerobic pond was beneficial in the prevention and minimization of odors. Without recirculation, there were odor problems with the anaerobic pond.

The use of waste water treatment lagoons for the propagation of fish at plants in California has been investigated and has been reported by industry representatives to have met with only partial success.

Laboratory studies have been conducted by the British Columbia Research Council to determine the feasibility of using aerated lagoons to treat waste flume waters. The studies also provided data on optimum load conditions, determination of the time required in startup relative to the beginning of the campaign, and adaptability of the aerated lagoon method to intermittent operation and to temperature change. The waste flume water was obtained from a plant with a high degree of recycling and the initial BOD_5 values ranged from 821 to 1121 mg/l. Effluent BOD_5 values ranged from 30 to 140 mg/l.

The efficiency of a lagoon system depends to a large degree on the climatic conditions, organic loading, and ability to maintain uniform flows through the lagoon system. Lagoon systems are effective in removing essentially all the suspended solids. Effluents of low BOD_5 can be attained only by maintaining long retention periods, which require large land areas. The water in the lagoons must be kept shallow, and water movement is preferable in order to avoid the generation of hydrogen sulfide with its attendant nuisance odors (28). Preliminary screening of beet sugar processing wastes to remove particulate organic matter before discharge to lagoons substantially lessens the occurrence and intensity of noxious odors.

Waste stabilization lagoons for treatment of beet sugar processing wastes would undoubtedly perform more efficiently in warm arid climates such as Southern California than those in northern, colder climates such as the Red River Valley of North Dakota and Minnesota. Relatively large land requirements for lagoons result where treatment of waste water for irrigation use is the primary objective. Lagoons must be located so as not to contribute to ground water pollution. Selection of the proper site by a qualified geologist to prevent pollution of nearby aquifers is a necessity.

Odors have been experienced with operation of some of the stablization lagoons in California. The settling pond and the initial anaerobic ponds in some cases have been found to be covered by a heavy proteinaceous scum layer, and the anaerobic ponds at times have produced serious odors. The utilization of purple sulfur bacteria (Thiopedia and Chromatium) has been a recent innovation and has been quite effective for odor control in waste treatment lagoons in California. The bacteria impart a pinkish-to-reddish color to the pond surface and serve as biological deodorizers by converting hydrogen sulfide photosynthetically to produce elemental sulfur and sulfates. Where these bacteria are present in sufficient numbers, hydrogen sulfide odors are usually greatly diminished or eliminated. Experience with the use of these bacteria for odor control has shown that although they are quite effective in warm climates they are less efficient under the cooler climatic conditions existing at Hereford, Texas.

Chemical Treatment - Although chemical additives are in fact used throughout the beet sugar process cycle, this discussion is limited to chemical flocculation as a unit operation employed in waste treatment.

Studies at one operation offer a noteworthy example of waste treatment by chemical precipitation. Waste flume waters were received into a grit separator for heavy solids removal then treated by chemical flocculation, with 40 percent of the treated waters being returned to the beet flume and the remainder being discharged to the river. The sludges from both the grit separator and the setting basin were directed to sludge ponds and supernatants were returned to the grit chamber. This plant utilized dry handling techniques in moving the sugar beets from storage piles to the wet hopper. This resulted in minimum waste loadings in the flume system. The average BOD_5 level in the flume waters before treatment was 223 mg/l. Treatment results showed that the chemical flocculation system obtained 90 percent removal of suspended solids, and reduction of final BOD_5 levels between 70 and 130 mg/l or a 57 percent reduction in BOD_5 content, equal to a residual waste load of 0.43 kg/kkg (0.86 lb/ton) of beets processed. Other plant wastes were not accounted for in the total waste balance. These included the continuous discharge of excess condenser waters and some overflow from the lime mud ponds to the river.

The British Columbia Research Council has given preliminary attention to chemical flocculation as a polishing means following activated sludge treatment. The Council found that effluents from aeration units were measurably improved by adding lime or lime together with a coagulant aid.

Polymers to promote solids settling in mechanical clarifiers have been used with success at the Winnipeg, Manitoba, plant in Canads. In the United States polymers have not received widespread use because improvement of settling in the flume water is made with the addition of lime to flume waters in the mechanical clarifier or the earthen holding ponds.

Land Irrigation - The use of treated beet sugar processing waste waters for irrigating agricultural lands directly or indirectly is widely practiced throughout the western United States. Examples of this practice exist at plants in California and Texas, and in the South Platte River Basin in Colorado. Beet sugar processing wastes are applied directly to agricultural lands when the processing campaign coincides with the growing season. This is true for the warmer climates such as those existing in California. Over much of the remaining western United States the waste waters are generally stored in ponds or reservoirs until irrigation commences the following spring. A high degree of water reuse in the water-short areas of the western United States, predominantly for agricultural irrigation, is strongly reinforced by western water law.

Irrigation in general does not require a high degree of water quality, and often results in a completely consumptive use of the waste waters, with no resultant discharge of waste waters to surface waters under properly controlled conditions.

Activated Sludge - It has been shown on a pilot scale basis that activated sludge can effectively reduce the organic load in waste flume waters by 83 to 97 percent. The maximum time required in fully adapting the floc to the substrate was less than 96 hours. Bio-oxidation of beet sugar wastes at about 24°C (75°F) was successful, and initial BOD_5 values of 1035 to 2,000 mg/l were lowered to less than 50 mg/l within 20 to 30 hours.

Pilot plant evaluation of activated sludge treatment at Hereford, Texas, has provided favorable results. The study showed that an activated sludge system could produce good organic removals, but the system was rather easily upset. A system loading of 1 kg COD/kg (1 lb/lb) of mixed liquor volatile suspended solids/day with 3,000 to 4,000 mg/l mixed liquor volatile suspended solids concentration was suggested.

Laboratory activated sludge units were also used in Great Britain for treating waste waters received from a plant settling pond. Aeration periods varied from 6 to 24 hours. The first three runs used aeration times of 6 to 17 hours and provided BOD_5 reductions of 48 to 83 percent. The active floc may not have been fully adapted to the waste in these runs. Five other runs using aeration times of 18 to 24 hours produced BOD_5 reductions in the range of 89 to 95 percent. Initial BOD_5 values in the above tests were approximately 400 mg/l. When pond muds were used as a source of innoculum, startup rates were slower than desirable, but with an established active floc, the rates of BOD_5 removal were entirely adequate to handle high BOD_5 loadings. Maximum BOD_5 removal rates for flume wastes, employing an active floc, were obtained within 96 hours. A later report of experiments in which flume wastes from 38 beet sugar plants were subjected to bio-oxidative treatment showed that significant BOD_5 reduction was obtained after 72 hours startup period with aerobic treatment.

Trickling Filters - Trickling filter studies undertaken in Texas and Idaho and at many full-scale installations in Great Britain and Western Europe have suggested that such filters may have merit in beet sugar processing waste treatment. On the other hand, two full-scale trickling filter treatment plants have been constructed for the treatment of beet sugar processing wastes in the United States (Idaho and Utah). In both cases treatment performance was most disappointing, and both plants have since been closed. The failures were largely attributed to a gross underestimation of the waste water production rate and difficulty in design and selection of treatment units at these plants.

In Idaho, a conventional trickling filter plant was completed in the summer of 1965 to provide treatment of wastes expected from the Rupert plant during the following campaign. Lime mud slurry was separately impounded, and other plant wastes which comprised essentially the flume and condenser waters were directed for treatment. The facility consisted of a screen station with six vibrating screens in parallel, twin hydro-separators also arranged in parallel followed by a primary settling tank, a single high-rate trickling filter, secondary settling tank, and a brush aerator installed on the effluent discharge canal. The hydroseparators provided for removal of the heavier solids; flows in excess of 347 l/sec (5,500 gpm) through the separators were returned to the beet flumes. From the separators, the waste water entered the primary clarifier which was approximately 37 m (120 ft) in diameter and 3.1 m (10 ft) deep and provided a waste retention period of about 2.5 hours. The treatment plant was grossly overloaded, and only 189 l/sec (3,000 gpm) of settled waste water was subsequently applied to the trickling filter; the remaining 158 l/sec (2,500 gpm) was discharged to the receiving stream. Sludges from both the separators and primary settler were pumped to a storage pond. The trickling filter was approximately 60 m (200 ft) in diameter and 3 m (10 ft) deep, and contained 5.1 to 5.2 cm (2 to 6 in) slag material. The slag material was not uniformly distributed within the filter. The recirculation ratio was about 3:1 for this single stage filter. Filter effluent was then received into the secondary clarifier, and the final effluent was released into the receiving stream. The design plans specified 3,200 kkg (3,500 ton) of beets/day to be processed by the Rupert plant; however, during the very first campaign the average processing rate actually amounted to 5,900 kkg (6,500 ton)/day. Treatment plant overload was inescapable and drastic. Although firm data were not available concerning Rupert, it was estimated that the hydraulic load onto the trickling filter approximated 234 million l/ha/day (25 million gal/ac/day), and that the waste load was in the order of 12.6 to 21.6 kg $BOD\underline{5}$/cu m of filter media/day (7 to 12 lbs $BOD\underline{5}$/cu yd of filter media/day) including recirculation (13). These applied loads are extremely high. Besides poor distribution of media, there was little or no visible biological growth on the surface of the filter. Water vapor forming over the filter during cold weather retarded air movement in the filter bed, thereby tending to provide insufficient air supply to the bed. Provisions for including air undercurrents through the side and bottom of the bed possibly would have alleviated this condition (13). Furthermore, an automatic skimming device on the primary settler would have aided in removing the substantial accumulation of scum and grease present. Information obtained on Rupert indicated that the treatment plant was providing around 30 to 40 percent BOD5 removal for that portion of the beet sugar processing wastes receiving treatment. The conditions described above were observed principally during the 1965 and 1966 season and do not reflect changes since that time.

The trickling filter in Utah was constructed in 1961 and was intended for treating and recycling waste flume water. During the off-season the filter received various wastes from the plant holding pond. The facility consisted of a screen station, a grit chamber, and a mechanically-operated clarifier 37 m (120 ft) in diameter by 3.0 m (10 ft) deep, followed by a single trickling filter 37 m (120 ft) in diameter by 1.5 m (5 ft) deep. Two and one-half hours waste detention was provided in the primary settler. A portion of the filter effluent could be returned to the clarifier. The treatment system was reported in 1963 to have major defects. Serious deficiencies in the trickling filter included a poor underdrainage system and improper media specifications. The underdrain system experienced frequent flooding and required additional pumping capacity. Compaction of the media and damage to the underdrains were suspected. The reduction of media interspace served to minimize air circulation through the filter and retarded biological growths. The Lewiston plant wastes also indicated an inorganic nutrient deficit which may have caused even further difficulty in treatment.

Operation of the filter was initiated too late in the 1961 season to develop adequate biological growth. The filter was reactivated in March, 1962, using holding pond wastes. The results collected during March - May, 1962, showed 0 to 30 percent BOD5 reduction, with hydraulic and organic loads (including recirculation) of 43,900 cu m/ha/day (4.7 million gal/ac/day) and 10.8 kg BOD5/cu m of filter media /day (6 lbs BOD5/cu yd of filter media/day), respectively. Through June, 1962, the BOD5 removal increased to the 40 to 60 percent level, with applied filter loads of about 6.3 kg BOD5/cu m of filter media/day (3.5 lbs BOD5/cu yd of filter media/day). By November, 1962, the treatment plant BOD5 reduction dropped to a level of 10 to 50 percent.

Trickling filters have found wide favor at a number of beet sugar processing plants in Great Britain and Western Europe. Crane described the process by which some plants have contained the wastes in ponds from which the water is passed over trickling filters before discharge to a stream. During startup in the operation of the filters, it has been necessary to use waste dilution and recycle to avoid overloading the filter system. The contents of the pond are treated and discharged over a period of many months, with maximum BOD5 of the discharged effluent of less than 20 mg/l. Phipps of Great Britain has suggested that trickling filters offer one means of treating accumulated waste waters resulting from the integrated flume and condenser water recycling system. The waste water is stored over the campaign in a large pond and drawn off for treatment at a relatively slow rate throughout the year. The average plant would probably require storage capacity of 75.7 to 113.6 million liters (20 to 30 million gal). Phipps preferred a shallow rather than a deep pond to take advantage of wind mixing and aeration. Research was conducted in this regard, using an 8.1 ha (20 ac) lagoon and a percolating filter 18.3 m (60 ft) in diameter and 1.8 m (6 ft) deep. Filter inflow was diluted with stream water, and ranged from 17 to 230 mg/l BOD$_5$; the filter outflow ranged from 7 to 71 mg/l BOD$_5$. The results showed the filter system produced BOD5 reductions from 60 to 90 percent.

The full-scale waste treatment system at the Bardney beet sugar processing plant in Great Britain consisted of a single filter operating either at low- or high-rate application and receiving settling pond effluent diluted with river water before filter dosing. The pond effluent varied in BOD$_5$ concentrations from 1239 mg/l in March to about 38mg/l in October. The waste water temperature varied from 4 to 16°C (39 to 60°F), and filter loadings ranged from 0.13 to 1.39 kg BOD$_5$/cu m of filter media/day (0.07 to 0.77 lbs BOD$_5$/cu yd of filter media/day) with an average load around 0.72 kg BOD$_5$/cu m of filter media/day (0.4 lbs BOD$_5$/cu yd of filter media/day). Total waste volume treated was 144 million l (38 million gal). BOD$_5$ reductions varied from 55 to 97 percent, with removals of 83 percent or higher occurring in 9 of the 12 months. Final effluent BOD$_5$ values were approaching 20 mg/l. British studies have shown that properly operated filters could consistently produce effluents with less than 20 mg/l BOD$_5$ when the initial levels were between 105 and 180 mg/l. In starting operation of a filter, domestic sewage was recommended to be applied together with the beet sugar processing waste to reduce the time required for full filter adaptation. Primary and secondary settling were considered essential, and it was further recommended that for every 100 mg/l BOD$_5$, the waste water should contain a phosphorous equivalent not less than 1 mg/l. A reference was made to Russian experiences where strong beet sugar wastes of 4,000 to 5,000 mg/l BOD$_5$ have been directly applied at low loading rates to a three-stage filter system resulting in 75 to 85 percent BOD$_5$ reduction.

Recirculation - Reuse Systems - For plants presently utilizing pollution control technology, recirculation-reuse systems, biological treatment, and land application systems are being used to achieve waste load reduction. The nearly-closed waste water recirculation system represents the best level of rigorous waste water control, and has generally proved to be superior to biological methods in terms of overall results.

Flume Water Recycle Systems - A flume water recirculation circuit can be described as one with continuous recycling of flume waters and with essential treatment units in the line, thus providing efficient water reuse. Flume water recycling systems are in use or are planned at essentially all beet sugar processing plants. The extensive recycling flume water system commonly in place or planned at beet sugar processing plants has largely eliminated pollution originating from fecal coliforms in total process waste water.

Mechanical clarifiers providing generally a 30-minute detention period with lime addition may be employed for settling of flume water. Mechanical clarifiers are preferred because they provide better pH control of the recycling operations and require less land. Sludge withdrawn from the clarifier or earthen pond facilities is generally conveyed to a mud holding pond for complete retention. Overflow from the mud holding pond is contained in subsequent holding facilities. In most cases where land is available, flume mud is allowed to accumulate within the pond without removal. However, the accumulated mud at the plant at Longmont, Colorado (an initial experimental project sponsored by the Beet Sugar Development Foundation and Federal Water Pollution Control Administration) must be periodically removed from alternate mud settling ponds for disposal on adjacent land. Industry personnel report the cost of removing the accumulated solid material from the pond at approximately $15,000 per campaign or approximately 66 cents per cu meter (50 cents per cu yard) of solid material removed.

Condenser Water Recycling Systems - Partial or extensive recycling of water for barometric condenser purposes or reuse is widely practiced in the industry. A total of 16 plants accomplish maximum recycling of condenser water within the plant, the only waste water discharged being that necessary for total dissolved solids control in the system to prevent excessive scaling. The discharged volumes are almost universally disposed of through land application without discharge to navigable waters.

Integrated Flume and Condenser Water Recycling Systems - Condenser waters may be added into the flume recycle circuit because of the fluming process need for thawing of beets or other reasons. Many plants in Europe employ the integrated system in whole or in part. Integrated flume and condenser water systems are in use in two U. S. plants. One system was installed in 1956 and has as its basic components a screening station, mechanical settling tanks, sludge pond, spray pond, lime pond, excess water storage pond, and a distribution line leading from the excess water pond back into the plant. Reclaimed waters are pumped from the excess water pond to the plant main water supply tank which in turn serves to supply the beet flumes, beet washer, roller spray table, and condenser system, and for purposes of slurrying the lime mud.

Alternative methods of flume water recycling include separate discharge of condenser water, dry methods of conveying beets into the plant, or a combination of various inplant and treatment measures to achieve desired waste load reduction. A multiplicity of choices and process alternatives exists in the latter case. However, no discharge of process waste water pollutants to navigable waters is possible through mechanisms of water reuse and recycling in a beet sugar processing plant with control and disposal of excess waste water through land application of process waste waters.

One of the early systems was examined in 1962 by Force for possible improvement. Two areas were found to be of particular significance. First, separate flume and condenser water recycling systems would serve to reduce the high flume water temperatures existing in early fall. The addition of a spray pond or other cooling device would be desirable on the condenser water circuit. In colder weather, the two systems could be combined thus taking advantage of the warm condenser water which is desirable within the flume waters during colder weather. Second, the lime pond overflow should be eliminated from the circuit because of the many problems caused by high solids. Similar exclusion of sludge pond overflow would aid the circuit, although to a lesser extent.

Land Waste Water Disposal Without Discharge to Surface Waters - Waste disposal of all beet sugar processing wastes without discharge to surface waters may be accomplished through extensive inplant waste water recycling, waste water treatment and control, and/or land disposal. Any excess waste water is ultimately disposed of by evaporation and controlled filtration, or in some cases by use of waste water after treatment for irrigation.

One plant in the western U.S. practices remarkable recirculation and reuse of waste waters with very low fresh water intake of 900 l/kkg (215 gal/ton) of beets. Although large areas are available for ponding of wastes, actually little is used. There is no discharge to surface waters.

Mass Water Balance in a Beet Sugar Processing Plant

An account of water gains and losses that occur in a typical beet sugar processing operation is given in this subsection. Schematic diagrams of water balance (net gains and losses) for typical flume, condenser, and overall process operations are given in Figures VII, VIII, and IX respectively.

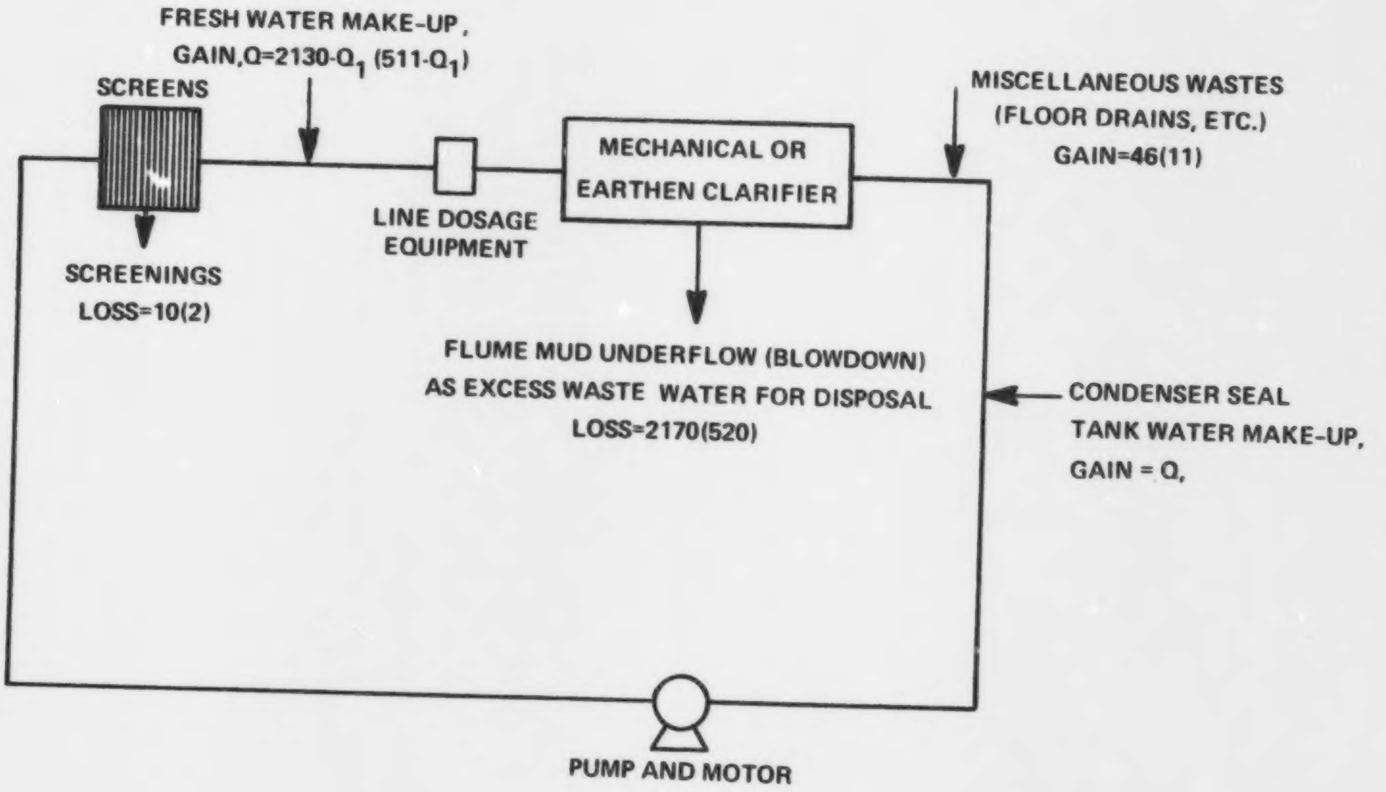
Water Gains

Water gains in a beet sugar processing plant result from incoming sugar beets and fresh water intake. Incoming beets normally have between 75 and 80 percent moisture. A moisture content of 80 percent is assumed in subsequent calculations.

Water from incoming beets (75-80% moisture) = 800 l/kkg of beets processed (192 gal/ton).

Figure VII

WATER BALANCE DIAGRAM FOR A TYPICAL BEET SUGAR PROCESSING PLANT
NET GAINS AND LOSSES [1] FOR FLUME WATER SYSTEM


FRESH WATER MAKE-UP,
GAIN,Q=2130-Q_1 (511-Q_1)
SCREENS
SCREENINGS
LOSS=10(2)
LINE DOSAGE EQUIPMENT
MECHANICAL OR EARTHEN CLARIFIER
MISCELLANEOUS WASTES
(FLOOR DRAINS, ETC.)
GAIN=46(11)
FLUME MUD UNDERFLOW (BLOWDOWN)
AS EXCESS WASTE WATER FOR DISPOSAL
LOSS=2170(520)
CONDENSER SEAL
TANK WATER MAKE-UP,
GAIN = Q,
PUMP AND MOTOR

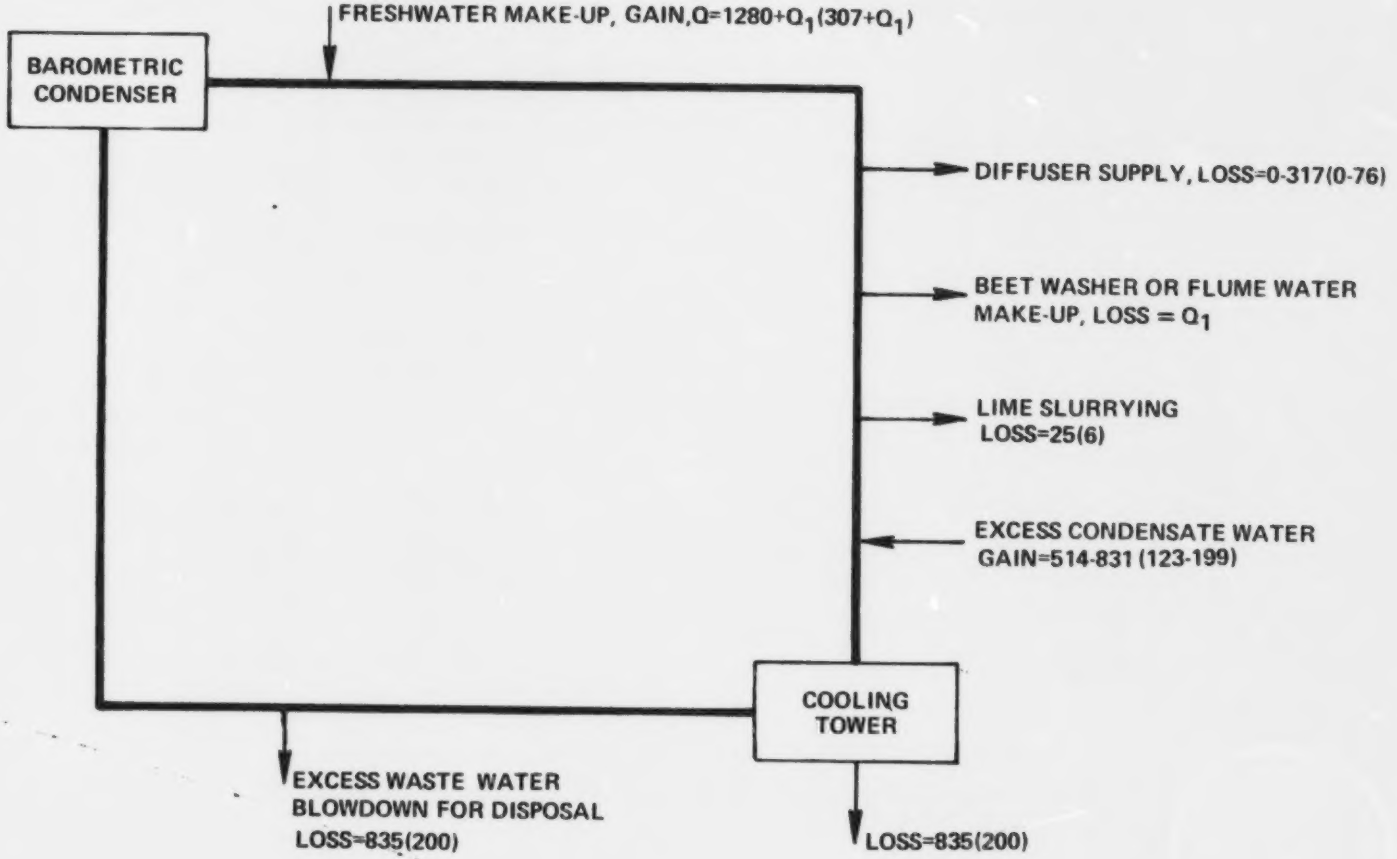
---

[1] All water gains and losses are expressed in terms of l/kkg. Expressions in terms of gallons per ton of beets sliced are indicated in parenthesis.

Figure VIII

WATER BALANCE DIAGRAM FOR A TYPICAL BEET SUGAR PROCESSING PLANT

NET GAINS AND LOSSES[1] FOR CONDENSER WATER SYSTEM


FRESHWATER MAKE-UP, GAIN,Q=1280+Q_1(307+Q_1)
BAROMETRIC CONDENSER
DIFFUSER SUPPLY, LOSS=0-317(0-76)
BEET WASHER OR FLUME WATER MAKE-UP, LOSS = Q_1
LIME SLURRYING LOSS=25(6)
EXCESS CONDENSATE WATER GAIN=514-831 (123-199)
COOLING TOWER
EXCESS WASTE WATER BLOWDOWN FOR DISPOSAL LOSS=835(200)
LOSS=835(200)

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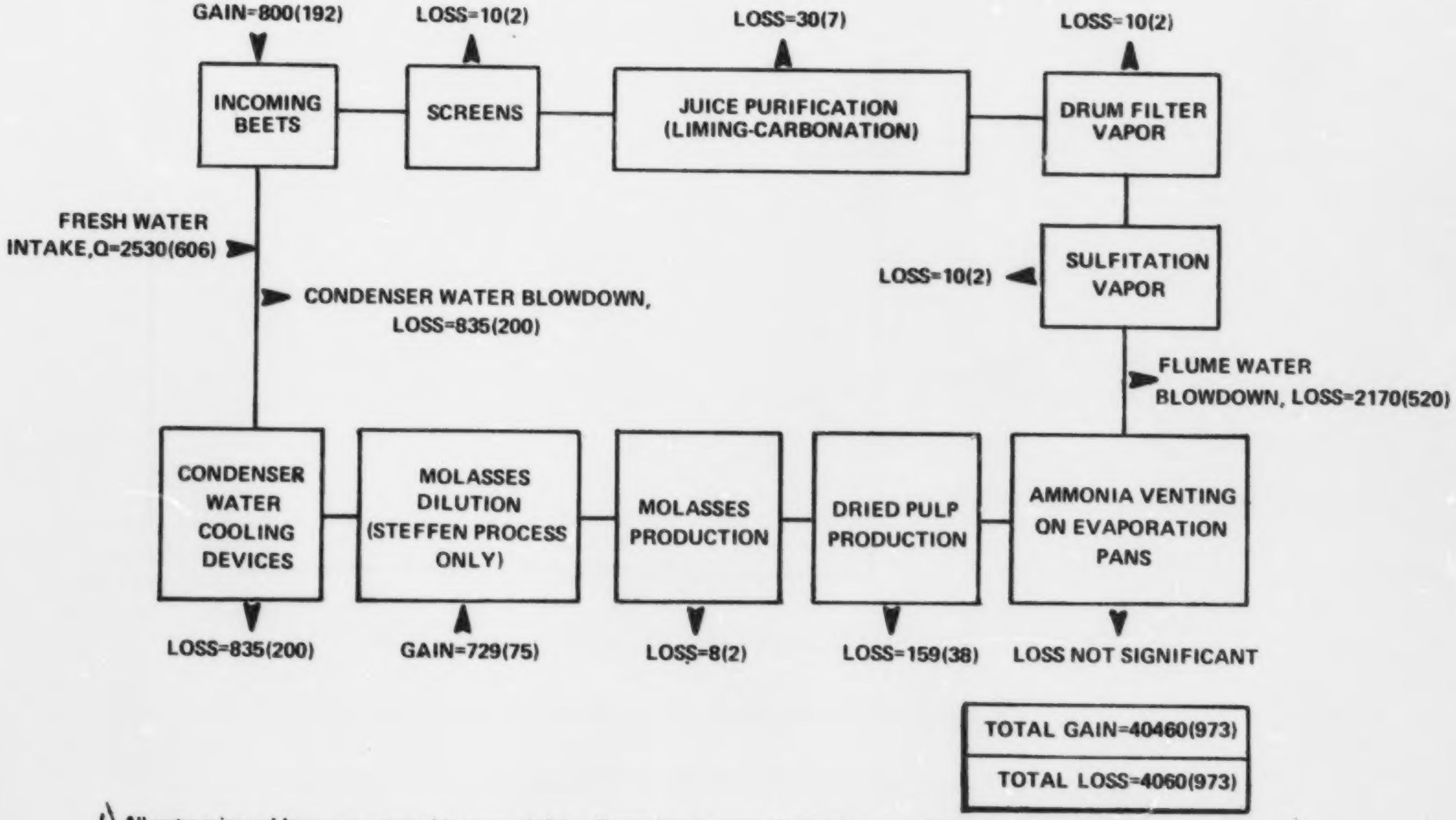
[1] All water gains and losses are expressed in terms of l/kkg. Expressions in terms of gallons per ton of beets sliced are indicated in parenthesis

Figure IX

WATER BALANCE DIAGRAM FOR TYPICAL BEET SUGAR PROCESSING PLANT
NET GAINS AND LOSSES △ FROM TOTAL PROCESSING OPERATION


GAIN=800(192)
INCOMING BEETS
LOSS=10(2)
SCREENS
LOSS=30(7)
JUICE PURIFICATION (LIMING-CARBONATION)
LOSS=10(2)
DRUM FILTER VAPOR
FRESH WATER INTAKE,Q=2530(606)
CONDENSER WATER BLOWDOWN, LOSS=835(200)
LOSS=10(2)
SULFITATION VAPOR
FLUME WATER BLOWDOWN, LOSS=2170(520)
CONDENSER WATER COOLING DEVICES
MOLASSES DILUTION (STEFFEN PROCESS ONLY)
MOLASSES PRODUCTION
DRIED PULP PRODUCTION
AMMONIA VENTING ON EVAPORATION PANS
LOSS=835(200)
GAIN=729(75)
LOSS=8(2)
LOSS=159(38)
LOSS NOT SIGNIFICANT
TOTAL GAIN=40460(973)
TOTAL LOSS=4060(973)

△ All water gains and losses are expressed in terms of l/kkg. Expressions in terms of gallons per ton of beets sliced are indicated in parenthesis.

The quantity of fresh water intake for a beet sugar processing plant is highly variable. Factors to be considered are chemical, physical, and temperature qualities of water supplies (ground water or surface sources), and water makeup requirements for solids and scaling control in recycled flume and condenser water systems. Total water requirements for flume and condenser water purposes amount to 10,840 l/kkg (2600 gal/ton) of beets sliced and 8360 l/kkg (2000 gal/ton) of beets sliced, respectively (49). Industrial experience has shown that approximately 20 percent or less water makeup in volume is required to compensate for evaporative losses and to maintain scaling control in a recycling condenser water system. Fresh water makeup in the recycled flume water system is limited by the need for particulate solids removal and approximates 20 percent of total volume based on existing practices. This would amount to a fresh water volume make-up of 2170 l/kkg (520 gal/ton) of beets sliced and 1670 l/kkg (400 gal/ton) of beets sliced for the recirculating flume and condenser water systems, respectively. In a recirculating barometric condenser water system, approximately 10 percent water volume may be attributable to evaporative water losses in cooling, the remaining being attributed to "blowdown" from the system for solids control. Essentially the entire 20 percent water volume in the recirculating flume water system may be attributed to "blowdown" associated with solids control.

Water losses in the plant result from:

- Wet weeds and leaves
- Carbonation tank venting
- Drum filter vapor
- Sulfitation vapor
- Ammonia venting on evaporators
- Pulp drying
- Molasses production
- Molasses dilution (Steffen process only)
- Cooling devices

Wet weeds and leaves contribute to water loss in the plant. Iverson (75) estimates that the moisture content of wet weeds and leaves equals one percent of the weight of beets sliced. This amounts to 10 l/kkg of beets processed (2.4 gal/ton).

Small amounts of water vapor are lost through venting of carbonation tanks. This water quantity is estimated by Iverson (75) to be 3 percent by weight of beets processed.

Carbonation tank venting water loss = 30 l/kkg of beets processed
(7.2 gal/ton)

Drum filter vapor is another source of water loss estimated by Iverson (75) to be 1 percent by weight of beets processed.

Drum filter vapor = 1 percent by weight of beets processed
water loss = 10 l/kkg of beets processed
= (2.4 gal/ton)

Sulfitating of the purified and clarified thin juices is conducted to control juice color formation, to improve the boiling properties of the juices, and to reduce excess alkalinity. Liquid sulfur dioxide is introduced directly into the thin juice pipeline from the second carbonation filters.

Sulfitation vapor water loss = 1 percent of the beets sliced by weight = 10 l/kkg of beets processed (2.4 gal/ton)

Some small undetermined water loss occurs through ammonia venting lines on the steam chest of multi-effect evaporators. The venting lines and valves are periodically opened to bleed off small accumulations of ammonia gas in the evaporators.

Pulp drying produces the largest single loss of water in a beet sugar processing plant.

Weight of dried pulp (7-10 percent moisture) = 45 kg/kkg of beets sliced (94 lbs/ton)

Water in dried pulp (7-10 percent moisture) = 2.9 l/kkg of beets processed (0.7 gal/ton)

Water loss in pulp drying operation = 159 l/kkg of beets sliced (38 gal/ton)

Iverson (75) reports a total water loss through dryer exhaust of 15 percent of beets processed. Water loss would then account for 150 l/kkg of beets processed (36 gal/ton).

The values of 159 and 150 l/kkg of beets sliced (38 and 36 gal/ton) are in close agreement. A water loss value of 159 l/kkg of beets sliced (38 gal/ton) is selected.

Molasses production in a straight-house operation ranges between 4 and 6 percent by weight of the beets sliced (65). Total molasses production is taken at 5.5 percent by weight of sliced beets (standard industry parameter). A typical analysis of beet sugar molasses is 85 percent dry substance and 15 percent water.

Total molasses produced (5.5 percent by weight of beets sliced) = 55 kg/kkg of beets sliced (110 lbs/ton)

Water in molasses (15 percent) = 8.3 l/kkg of beets sliced (2 gal/ton)

Iverson (75) reports the loss of water in molasses produced of 1 percent of the weight of beets sliced equals 10 l/kkg (2.4 gal/ton) of beets sliced. The values of 8.3 and 10.0 l/kkg (2.0 and 2.4 gal/ton) of beets sliced are in general agreement. A value of 8.3 l/kkg (2.0 gal/ton) of beets sliced is taken.

Solids in molasses = 0.85(55 kg/kkg)
= 47 kg/kkg of beets sliced (94 lbs/ton)

Approximately 30 percent of molasses produced (maximum) may be disposed of on dried beet pulp for animal feeds, or molasses by weight of beets sliced (standard industry practice).

Molasses disposed of on pulp (30% of total molasses produced)
= 0.021x1000 kg/kkg
= 21 kg/kkg of beets sliced
(42 lbs/ton)

Water in molasses disposed of on pulp = 3.2 l/kkg of beets sliced (0.8 gal/ton)

Water in molasses not disposed of on pulp = 5.1 l/kkg of beets sliced (1.2 gal/ton)

Straight-house molasses containing 85 percent dry substance by weight is diluted with water to approximately 6 percent sugar for processing in the Steffen process.

Solids in straight-house molasses=45 kg/kkg of beets sliced (90 lb/ton)

Weight of molasses after dilution=783 kg/kkg of beets sliced (1566 lb/ton)

Weight of water in diluted molasses = 736 kg/kkg of beets sliced (1472 lb/ton)

Volume of water in diluted molasses (Steffen house) = 736 l/kkg of beets sliced (176 gal/ton)

Required dilution water for molasses = 736 - 7 or 729 l/kkg of beets processed (175 gal/ton)

Cooling devices (spray ponds, open cooling ponds, cooling towers, etc.) result in evaporative water losses in the process of cooling condenser and other heated waters. Cooling towers account for an evaporative loss of 10 to 15 percent of the total condenser water volume of 8350 l/kkg of beets processed (2000 gal/ton) of beets sliced. A 10 percent evaporative loss through cooling of condenser water is assumed where cooling devices are employed for condenser water (835 l/kkg of beets processed) (200 gal/ton).

In-plant Water Uses

Pulp press water originates from the pressing of exhausted beet pulp removed from the diffuser.

Weight of wet pulp from diffuser (80 percent of beets sliced by weight = 800 kg/kkg of beets processed (1600 lbs/ton)

Water contained in wet pulp from the diffuser (95 percent moisture = 764 l/kkg of beets sliced (183 gal/ton)

Dry solids in wet pulp from diffuser = 40 kg/kkg of beets sliced (80 lb/ton)

Water contained in the exhausted pulp after pressing ranges between 76 and 84 percent. Eighty percent moisture of pressed pulp is common.

Weight of wet pulp after pressing (80 percent moisture) = 200 kg/kkg of beets sliced (400 lbs/ton)

Water contained within pulp after pressing (80 percent moisture) = 163 l/kkg of beets sliced (39 gal/ton)

Water extracted by pulp pressing = 764 - 163 = 601 l/kkg of beets sliced (144 gal/ton)

The diffusion process involves the extraction of sucrose from sliced beets. The sugar-laden liquid (raw juice) and exhausted pulp resulting from the process are used subsequently in the processing operation. Total diffuser supply water is normally made up by 65 percent from pulp press water of 601 l/kkg (144 gal/ton) of beets sliced which is returned to the diffuser. Estimated total diffuser supply on this basis equals 918 l/kkg of beets sliced (220 gal/ton).

Raw or diffusion juice has 12 to 15 percent solids or sugar, which is about 98 percent of the sugar which was contained in the beets when sliced. Fifteen percent solids in diffusion juice is assumed (standard industry parameter). Fifteen percent sucrose content is a normal figure for sugar beets.

Sugar contained in diffusion juice = 0.15 x 1000 x 0.98 = 147 kg/kkg of beets processed (294 lbs/ton)

Total weight of diffusion juice = 983 kg/kkg of beets sliced (1960 lb/ton)

Weight of water contained in diffusion juice = 836 kg/kkg of beets sliced (1670 lbs/ton)

Volume of water in diffusion juice = 835 l/kkg of beets sliced (200 gal/ton)

Raw juice "draft" normally runs between 100 and 150 percent in the diffusion process (120 percent is used in this calculation).

Draft (percent) = (Weight of diffusion juice drawn from diffuser

÷ Weight of cossettes introduced as beets sliced) x 100

Weight of raw juice from diffuser = 1200 kg/kkg of beets sliced (2400 lbs/ton)

Weight of solids in raw diffusion juice = 180 kg/kkg of beets sliced (360 lbs/ton)

Weight of water in raw diffusion juice = 1020 kg/kkg of beets sliced (2040 lbs/ton)

Volume of water in raw diffusion juice = 1020 l/kkg of beets sliced (245 gal/ton)

The diffusion process water supply requirements as determined by the somewhat different approaches as above of 835, 918, 1020 l/kkg of beets sliced (200, 220, and 245 gal/ton) are in general agreement. A value for total diffuser water supply requirements of 918 l/kkg of beets sliced (220 gal/ton) is taken as an industry-wide practice. On the basis of total water supply requirements for diffusion purposes of 918 l/kkg of beets sliced (220 gal/ton) and return of 600 l/kkg (144 gal/ton) of beets sliced of pulp press water to the diffuser, requirements for diffuser water makeup from other sources (condensate water, condenser water, etc.) would be 918 - 600 = 318 l/kkg of beets sliced (76 gal/ton)

Condensate water, generally the purest water source within the plant, is generated in large quantities through the process of concentrating the purified, thin juice after liming and carbonation. In the concentrating process, the raw juice is reduced from 10 to 15 percent solids to 50 to 65 percent solids. When raw juice is concentrated, water is produced in the concentration process through condensation of vapors from juice boiling. A typical juice concentration of 55 percent solids is taken as common practice (standard industry parameter).

Weight of solids in raw diffusion juice (15 percent solids) = 180 kg/kkg of beets sliced (360 lbs/ton)

Volume of water in raw diffusion juice = 1020 l/kkg of beets sliced (245 gal/ton)

Total weight of "thick" juice after concentration = 327 kg/kkg of beets processed (655 lbs/ton)

Weight of water in "thick" juice after concentration = 148 kg/kkg of beets sliced (296 lbs/ton)

Total condensate water produced from concentration of raw juice = 1022 - 146 = 876 l/kkg of beets sliced (210 gal/ton)

Condensate water is commonly used for boiler feed and makeup diffuser supply, floor washing, or other uses in the plant. Vapors in multi-effect evaporation are used sequentially in evaporators for heating effects. Excess vapors from evaporation are generally used for heating purposes. Condensate from the first evaporation effect is generally preferred for the supply of diffuser water. Condensate from the second through fifth evaporator effects is employed for boiler feed, washing filters, washing floors, and diffuser water makeup.

Total condensate volume (918 l/kkg of beets sliced) (220 gal/ton) may be attributed to diffuser supply (317 l/kkg of beets sliced) (76 gal/ton), floor washings (46 l/kkg of beets sliced) (11 gal/ton), and an excess of approximately 510 l/kkg of beets processed (123 gal/ton). The excess condensate volume is not generally metered, and is usually discharged to the condenser water system. Condensate water is essentially pure and may be satisfactorily used for makeup water in barometric condenser systems for total solids control.

Boiler feed is supplied by condensate water from the first, second and third pan evaporation processes. The steam has a temperature and pressure of about 302°C (575° F) and 28.2 atm (400 psi). The pressure of the exhaust steam after power generation is 4.1 atm (45 psi). Makeup required by the necessity of blowdown for solids control in the boiler system is reported normally to account for 4 percent of the generated steam.

Press water is supplied directly from condensate water from the fourth and fifth effect evaporators, overflow from the boiler feed system, and miscellaneous other sources such as second high raw and evaporator pans, heaters, and juice boilers. The press water is used for washing lime mud during dewatering of precipitated lime from juice purification on the vacuum filter. The combined filtrate and wash water from the rotary vacuum filters is called "sweet water," and this is used to supply milk of lime in a straighthouse or saccharate milk in a Steffen house. Excess "sweet water" is returned to first or second carbonation stages. The quality of condensate water utilized for press water is unknown and is not metered at most plants. No reliable estimate can be made.

Floor washing is accomplished with condensate water use as high as 192 l/sec (50 gpm) at one 5900 kkg/day (6500 ton/day) beet sugar processing plant. The quantity of water used for floor washing would be expected to be largely independent of plant size. Water use is approximately = 46 l/kkg of beets processed (11 gal/ton).

Lime mud from vacuum filters is diluted with water from 50 percent to 40 percent solids to facilitate pumping to holding facilities.

Lime slurry volume = 375 l/kkg of beets processed (90 gal/ton)
Specific gravity of solids $Ca(OH)_2$ = 2.08

Weight of solids in lime slurry = 23 kg/kkg of beets processed
(46 lb/ton)

Weight of water in lime slurry = 22 kg/kkg of beets processed
(44 lb/ton)

Volume of water in the lime slurry = 22 l/kkg of beets
processed (5.3 gal/ton)

Water use for lime slurrying is reported to be as high as 170
l/min (45 gpm) at one 5900 kkg/day (6,500 ton/day) plant = 41
l/kkg of beets processed
= (10 gal/ton)

The values, 22 and 41 l/kkg (5.3 and 10 gal/ton) of beets processed are in general agreement. A value of 25 l/kkg (6 gal/ton) of beets processed is taken as an industry-wide figure. The water used for lime slurrying may be provided from condenser water sources.

The mass water balance for the average-sized 3300 kg/day (3600 ton/day) beet sugar processing plant indicates the necessity to adequately dispose of 9.8 million l/day (2.6 million gal/day) of waste water generated over an average 100-day processing campaign.

The length of the processing campaign may be considerably longer in warm and arid climates, e.g. California (220 to 290 slice days); however, land availability and climatic conditions in these locations generally permit controlled land disposal of all process waste waters or reuse after treatment for crop irrigation purposes. Adequate disposal of process waste waters from beet sugar processing plants with no discharge to navigable waters can be accomplished through controlled land disposal.

Identification of Water Pollution Related Operation and Maintenance Problems at Beet Sugar Processing Plants

Improper design and control of biological-recirculation systems, variability of waste water quantities and qualities, and process variables can give rise to operation-related problems at beet sugar processing plants. These operational problems are generally related to reduced performance of waste treatment facilities, or odor and nuisance level control.

Variability in the quantity and qualities of flume water, condenser water, and floor washing can present difficulties in treatment of these wastes. Variability may often be accounted for as due to accidental spills and introduction of deteriorated beets into the fluming system.

Condensate water used as house hot water for evaporator and floor cleaning often requires the addition of acids or caustic soda. The wastes are generally discharged to the main sewer of the plant and the flume water system. The flow is intermittent and often results in sudden change in the pH of the waste water as discharged to ponds. This accounts in part for erratic behavior of waste treatment processes and is indicative of the need for satisfactory pH control facilities.

Improvement in the design and arrangement of new equipment for the industry should help prevent unintended losses of miscellaneous waste waters into the treatment and disposal system. Expanded use of automation will also assist in maintaining better plant control and reducing shock waste loads.

Difficult problems often result from the use of waste lagoons and mechanical clarifiers for treatment of beet sugar processing wastes. The problems incurred generally relate to improper operation and maintenance and result in offensive odors from the anaerobic conditions in these facilities. Screening of effluent wastes and periodic removal of accumulated solids can substantially reduce or minimize odor and nuisance-related problems.

Odors generated from various pollution control related operations are a problem at a number of plants. Plants have used various aeration devices in holding ponds and/or maintenance of shallow pond depths to control odors. Holding ponds may receive overflow from the flume mud pond, clarifier effluent from the flume system, and excess barometric condenser water. Aeration may be accomplished by means of a spray system. Mechanical aeration devices are often employed for the initial anaerobic pond of an extensive anaerobic-aerobic lagoon system for odor control.

Poor operation and maintenance (a practice at many plants) contributes to many difficulties. Where shallow ponds are employed for waste treatment, the failure to remove routinely accumulated solids when necessary from the ponds reduces the effectiveness of waste treatment. Improper waste retention results in low organic removal, solids carryover, and low bacteriological reduction efficiency. Waste retention is severely limited by solids filling, extensive weed growth, and unevenness of the pond bottom.

Of greatest concern in the recycling of flume water is control of odorous and corrosive properties of the recycled flume water. These factors are primarily related to the maintenance of alkaline pH conditions (pH 8-11) in the system, which is generally accomplished by the addition of lime under carefully controlled and monitored conditions. Lime addition also enhances the ability of solids to settle in the recirculated flume water system.

The leaching of sugar from beets which have been frozen is considerably higher than that from unfrozen beets in the flume system. Freezing and thawing of beets destroys the structural integrity of the outer beet fibers, releasing sugar contained in the beets to the flume waters. The dislodged fibers of the beets often pass through screening devices and are discharged to the flume water clarifier or earthern holding ponds. These conditions present nuisance-related problems and operational difficulties. Foaming within the flume and condenser water system is a major problem particularly during the latter part of the campaign in regions where processing of frozen beets is common practice. The foaming problem is particularly enhanced by low pH conditions.

Fecal streptococcus organisms are known to increase markedly in a recirculating flume water system. This growth has been found to increase as the processing season progresses. The bacterial growth presents no pollution or production-related problems in the recycling process. A final freshwater wash of the sugar beets before slicing is necessary for the sugar beets prior to processing for production control purposes.

The continuous processing of sugar beets over the entire processing campaign without "shut down" presents difficulties (particularly in older plants) with proper maintenance of acceptable housekeeping practices, and continuous operation of equipment. Because of the nature of the processing operation, leaks and breakages in waste water and molasses conveyance lines are not repaired promptly. Water hoses are frequently left running at intervals to control foaming, to flush spilled materials into drains, and for other purposes. These practices result in wasteful use of water with increased waste water contributions for subsequent treatment and disposal. Much improved housekeeping procedures are needed within the industry to minimize pollution, particularly at older plants. The beet sugar processing industry has recently made substantial efforts toward reducing pollution by improved housekeeping.

Improvements in the mechanical harvesting equipment for sugar beets are being made to the end that the crops will be received at the plants in cleaner condition. Improvements are also being made almost routinely in the equipment used for dry separation of the unwanted material from the sugar-bearing material.

Soil As A Waste Water Disposal Medium

With increasingly rigid pollution control standards for surface waters, emphasis has been placed in recent years on land disposal of industrial wastes and municipal sewage effluents. In land disposal of waste waters the soil acts as an effective filter in removal of particular contaminants. Aerobic biological action near the soil surface is effective in substantial removal of biodegradable organics. The soil particles are quite effective in removal of many substances, particularly phosphates, by absorption and ion exchange. Of concern in land disposal of waste waters is the current lack of complete knowledge of the hydrology and hydro-mechanics of the ground water region, with predictable regard for the fate and effects of subsurface pollutants. Dissolved materials derived from wastes water, particularly non-biodegradable inorganic salts, may tend to be persistent in ground waters inasmuch as the capacity of the soil to remove minerals by adsorption and ion exchange could be exhausted, with decreased efficiency with the passage of time. Effluent spraying on land has been demonstrated on a full scale basis with total nitrogen removals from waste water of 54 to 68 percent, and 76 to 93 percent removal of total phosphorus (101). Pollutant removal efficiencies are dependent upon soil loading and climatological conditions.

Agriculture is a major contributor to land disposal of wastes with some unknown contribution of ground water contaminants -- chlorides, nitrates, and non-biodegradable organic materials. Agriculture contamination of ground water is intensified in arid areas where ground water is used for irrigation process. Salt is inherently concentrated in the irrigation process with water intake by growing plants. Most contamination of ground waters within inland areas occurs from breaching of impervious barriers between fresh and saline waters. Ground water pollution problems are most evident in areas of intensive land use. The build-up of contaminants in ground waters from percolating pollutants is seldom dramatic, and sources of percolating pollutants are both diffuse and diverse.

In inland areas of the U.S. approxomately two-thirds of the coterminous region is underlain by saline waters containing greater than 1,000 mg/l disolved solids. This condition has resulted largely by natural geological factors with the washing of soluble salts from the soils in large basins where the salts have been concentrated by evaporation. Possible processes or combinations of processes for conversion of inland saline water as well as sea water to fresh water for agriculture, industrial, municipal, and other uses have been investigated since 1952 by the U.S. Dept. of the Interior under authority of Public Law 448. The Office of Saline Water, U.S. Department of the Interior, classifies any water containing from 1000 to about 35,000 mg/l as brackish. Sea water contains approximately 35,000 mg/l and water containing more dissolved solids than sea water, such as the Great Salt Lake, is classified as brine.

Processes for useful water conversion include vapor-compression methods, ion exchange, solar (multiple effects) distillation, freezing, osmotic processes, electrodialysis (membrane process), and ultrasonics. Ion exchange appears particularly promising when the concentration of dissolved materials is below 4000 to 5000 mg/l. Several plants applying this method have been constructed in recent years. At the present state of the art, large scale treatment of brackish waters with a comparatively low content of dissolved solids is possible. Most existing installations are limited in capacity, producing fresh water quantities of thousands of l/day rather than millions of liters daily. The membrane processes, reverse osmosis and electrodialysis, have their primary application in the desalting of brackish waters in the general range of 2000 to 10,000 mg/l of total dissolved solids. Large demonstration plants (1 MGD) have been constructed at Freeport, Texas, San Diego, California, and Roswell, New Mexico.

The cost of converting saline water has been reduced substantially during the last 10 years. Conversion cost ranges from about $0.6 to $1.50 per 3785 l (1000 gal) exclusive of distribution costs depending on the process used, the brackishness of the raw water, the capacity of the plant, and other factors. Desalination is an expensive process from the standpoint of capital investment and daily operating costs.

Industry in the United States consumed on an average about 2 percent of its total water use of 619 billion l/day (140 billion gal/day) in 1960. The heaviest consumption was in connection with irrigation where 60 percent or more of the water was lost to the water system through evaporation and transpiration. About 17 percent of water used for public supplies was consumed. Consumptive use of water was the quantity of water discharged to the atmosphere (evaporated) or incorporated in the products of the process in connection with vegetative growth, food processing, or incidentally to an industrial process.

In the western portion of the U.S. present salinity conditions resulting from irrigation return flows (approximately 40 percent of all water withdrawn from surface and ground sources in the United States is for irrigation) far outweigh the salinity contribution attributed to the beet sugar industry. Furthermore, the majority of beet sugar processing plants are located in low intensity land use areas.

Control of salinity and total dissolved solids contributions from beet sugar processing wastes can be accomplished without ground water pollution through associated with activated sludge growths in biological beds. proper location of land disposal sites regulation of waste water filtration rates consideration of geographical, hydrologic and gologic factors and conduct of an adequate monitoring program of nearby underground aquifers. At present all beet sugar processing plants incorporate land for disposal of all or part of the waste water flow. No serious ground water pollution problems are known to occur as attributed to these practices.

In any method of dissolved solids removal, concentrated salt solutions resulting as a byproduct of the process of desalting technology must be handled for ultimate disposal. The likely method for disposal of this material is land application under controlled conditions.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

Detailed cost data and pollution reduction benefit data of alternative treatment and control technologies applicable to the beet sugar processing subcategory of the sugar processing point source category are developed from supportive material for this document. The basic results are summarized below for an average-sized 3300 kkg/day (3600 ton/day) beet sugar processing plant.

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated at 5.8 kg BOD5/kkg (11.7 lbs BOD5/ton) of beets processed or 11.0 kg BOD5/kkg (22 lbs BOD5/ton) of beets processed including Steffen wastes for the selected typical plant at this minimal control level. Disposal of Steffen waste on dried pulp, byproduct recovery, or land disposal is assumed, as this is universally practiced in the industry. No control of lime mud slurry, flume water discharge, or condenser water flow is assumed. Pulp transport and press waters are recycled within the plant process.

Costs. None. Reduction Benefits. None.

Alternative B - Control of Lime Mud but Discharge to Receiving Streams of All Other Wastes

This alternative includes control of lime mud slurry in earthern holding ponds without discharge to navigable waters but no control for other wastes. This practice is used at all plants presently within the industry. Effluent waste load is estimated at 2.6 kg BOD5/kkg (5.1 lbs BOD5/ton) of beets processed for the better plant at this control level.

Costs. Increased capital costs are approximately $50,000 over Alternative A, thus total capital costs are $50,000.

Reduction Benefits. An incremental reduction in plant BOD5 of 57 percent compared to Alternative A is evidenced. Total plant reduction in BOD5 is also 57 percent.

Alternative C - Extensive Recycle of Flume Water Without Discharge to Navigable Waters

Under Alternative C there would be extensive recycle of flume water with no discharge of process waste water pollutants to navigable waters, incorporating treatment of flume water by screening and settling, and with mud drawoff to holding ponds for

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controlled land disposal. This technique is presently practiced by a large portion of the industry, 50 of 52 plants utilizing maximum or partial flume a large portion of the industry, 50 of 52 plants utilizing maximum or partial flume water recycling and all plants utilizing complete or partial land disposal of flume waters. Present industry plans call for complete installation of extensive flume water recycling systems by 1975. Effluent waste load is estimated at 0.25 kg/kkg (0.5 lbs BOD5/ton) of beets processed for a better plant at this control level. Presently, all but 8 plants employ maximum recirculating flume water systems.

Costs. Increased capital costs of $228,000 to $310,000 over Alternative B would be incurred, thus producing total capital costs of $278,000 to $360,000.

Reduction Benefits. An increment reduction in BOD5 of 90 percent in comparison to Alternative B would result, thereby producing a total reduction in plant BOD5 of 96 percent.

Alternative D - Extensive Recycle of Condenser Water Without Discharge to Navigable Waters

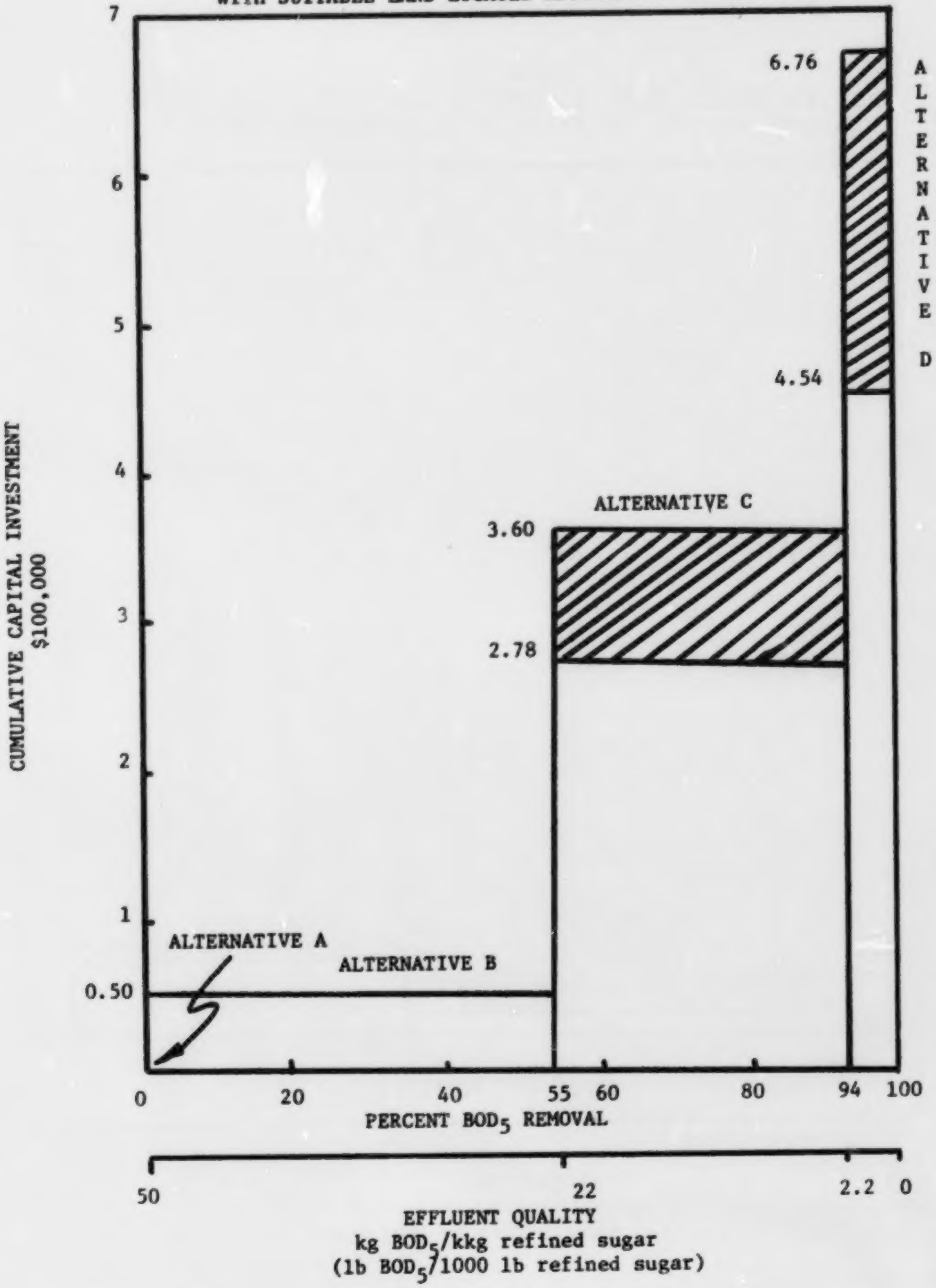
Alternative D would result in complete recycling of condenser water with land disposal of excess waste waters without discharge to navigable waters. Extensive water recycling and reuse within the plant process is assumed. Effluent waste load is zero kg BOD5/kkg (zero lb BOD5/ton) of beets processed for the better plants at this control level with complete land disposal of all process waste waters.

Costs. This alternative would require increased capital costs of $176,000 to $316,000 over Alternative C, or total capital costs of $454,000 to $676,000.

Reduction Benefits. There would be an increment reduction in BOD5 of 100 percent in comparison to Alternative C, and a total reduction in plant BOD5 of 100 percent.

In consideration of land availability factors as variables in the application of land-based technology for accomplishing zero discharge of process waste waters to navigable waters, the following four conditions are recognized as being applicable to existing plants within the beet sugar processing subcategory. The capital costs of the application of technology to accomplish zero discharge of all process waste waters to navigable waters is given for each of the various conditions in Figures X through XIV. Cost figures reflect land requirements based on a 0.635 cm/day (1/4-in/day) filtration rate, an average sized plant of 3300 kkg/day (3600 ton/day) capacity, and an average 100-day processing campaign. Land requirements for controlled disposal of excess process waste water resulting from beet sugar

FIGURE X
TOTAL COST EFFECTIVENESS RELATIONSHIP FOR COMPLETE LAND DISPOSAL WITH SUITABLE LAND LOCATED ADJACENT TO PLANT SITE

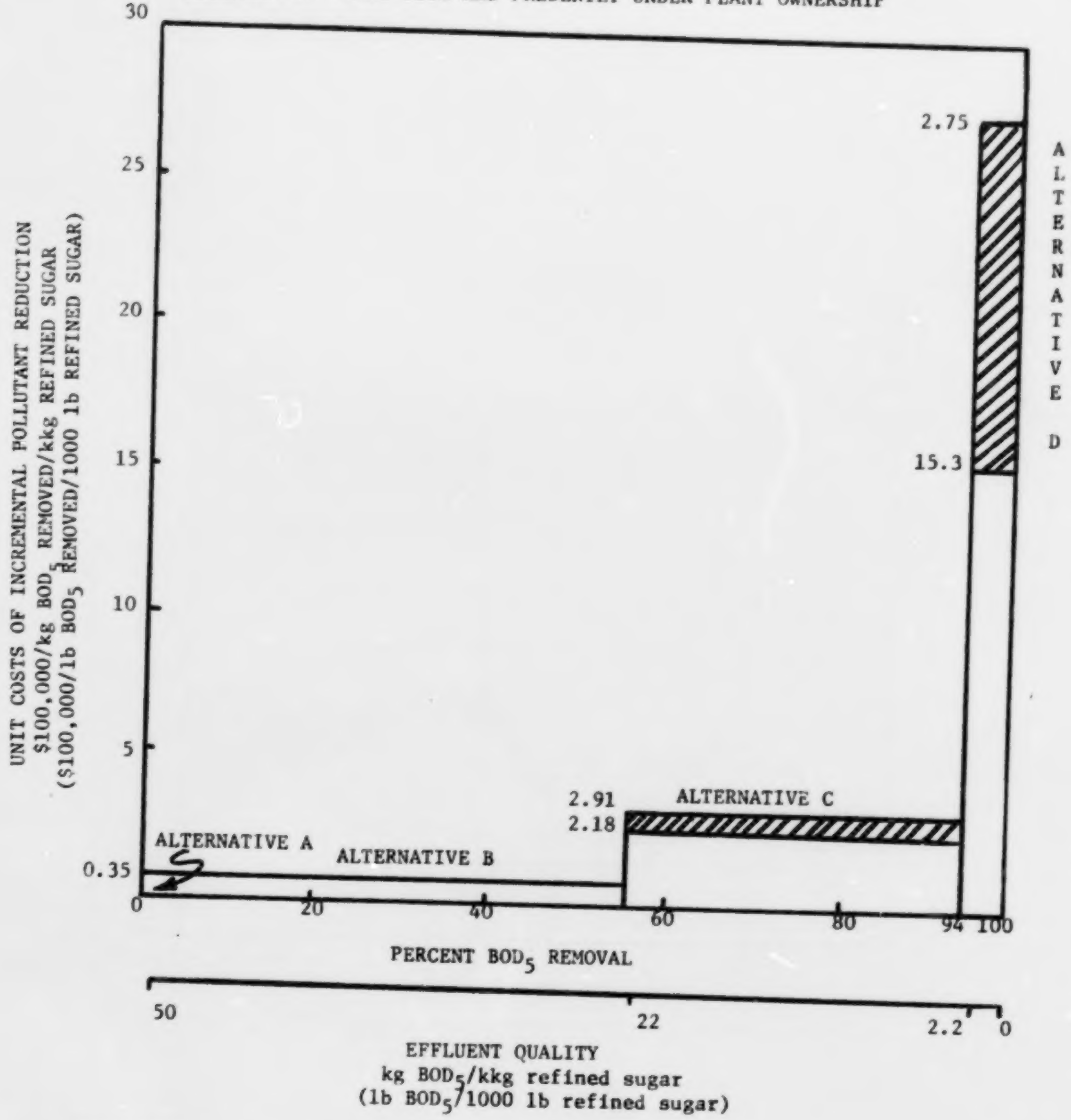


ASSUMPTIONS

1) LAND COST OF $4938/ha ($2000/ac) INCLUDING POND CONSTRUCTION AND FILTRATION CONTROL MEASURES
2) 377,728 kg REFINED SUGAR/DAY-PLANT (832,000 lb/DAY-PLANT)
3) 100 DAY CAMPAIGN
4) 0.635 cm/DAY (¼in/DAY) FILTRATION RATE

FIGURE XI

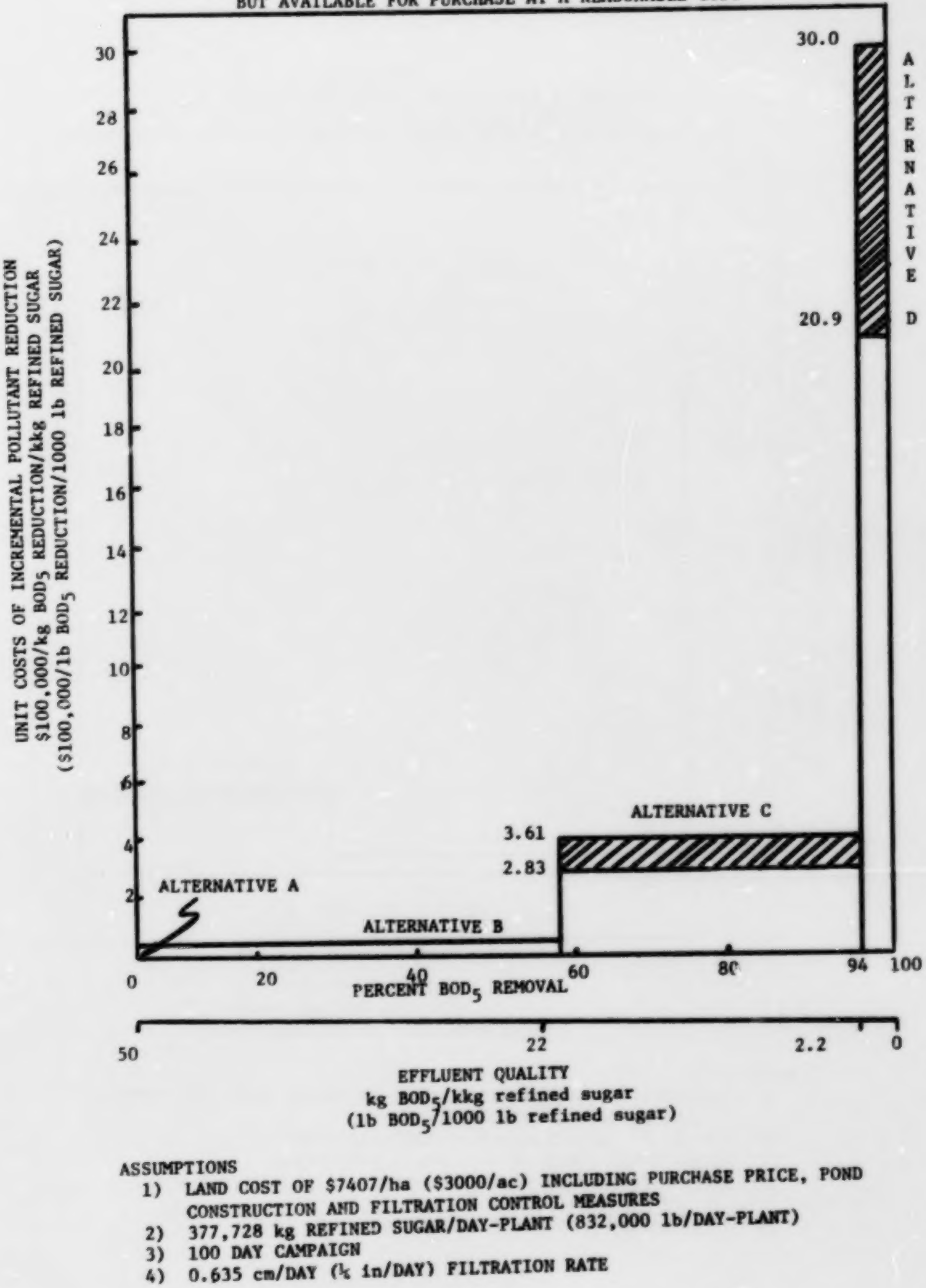
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND LOCATED ADJACENT TO PLANT SITE AND PRESENTLY UNDER PLANT OWNERSHIP



ASSUMPTIONS

1) LAND COST OF $4938/ha ($2000/ac) INCLUDING POND CONSTRUCTION AND FILTRATION CONTROL MEASURES
2) 377,728 kg REFINED SUGAR/DAY-PLANT (832,000 1b/DAY-PLANT)
3) 100 DAY CAMPAIGN
4) 0.635 cm/DAY (¼ in/DAY) FILTRATION RATE

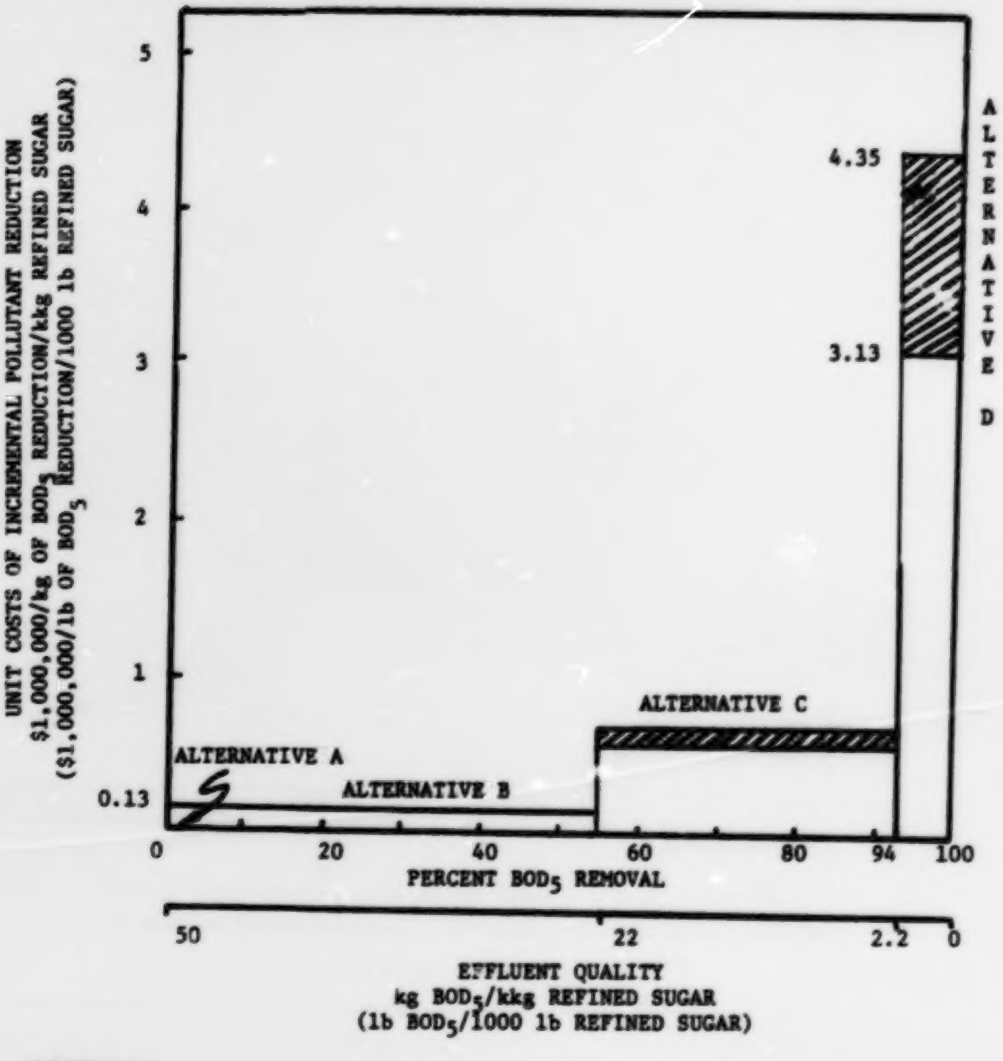
FIGURE XII
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND LOCATED ADJACENT TO PLANT SITE NOT PRESENTLY UNDER PLANT OWNERSHIP BUT AVAILABLE FOR PURCHASE AT A REASONABLE COST



ASSUMPTIONS

1) LAND COST OF $7407/ha ($3000/ac) INCLUDING PURCHASE PRICE, POND CONSTRUCTION AND FILTRATION CONTROL MEASURES
2) 377,728 kg REFINED SUGAR/DAY-PLANT (832,000 1b/DAY-PLANT)
3) 100 DAY CAMPAIGN
4) 0.635 cm/DAY (¼ in/DAY) FILTRATION RATE

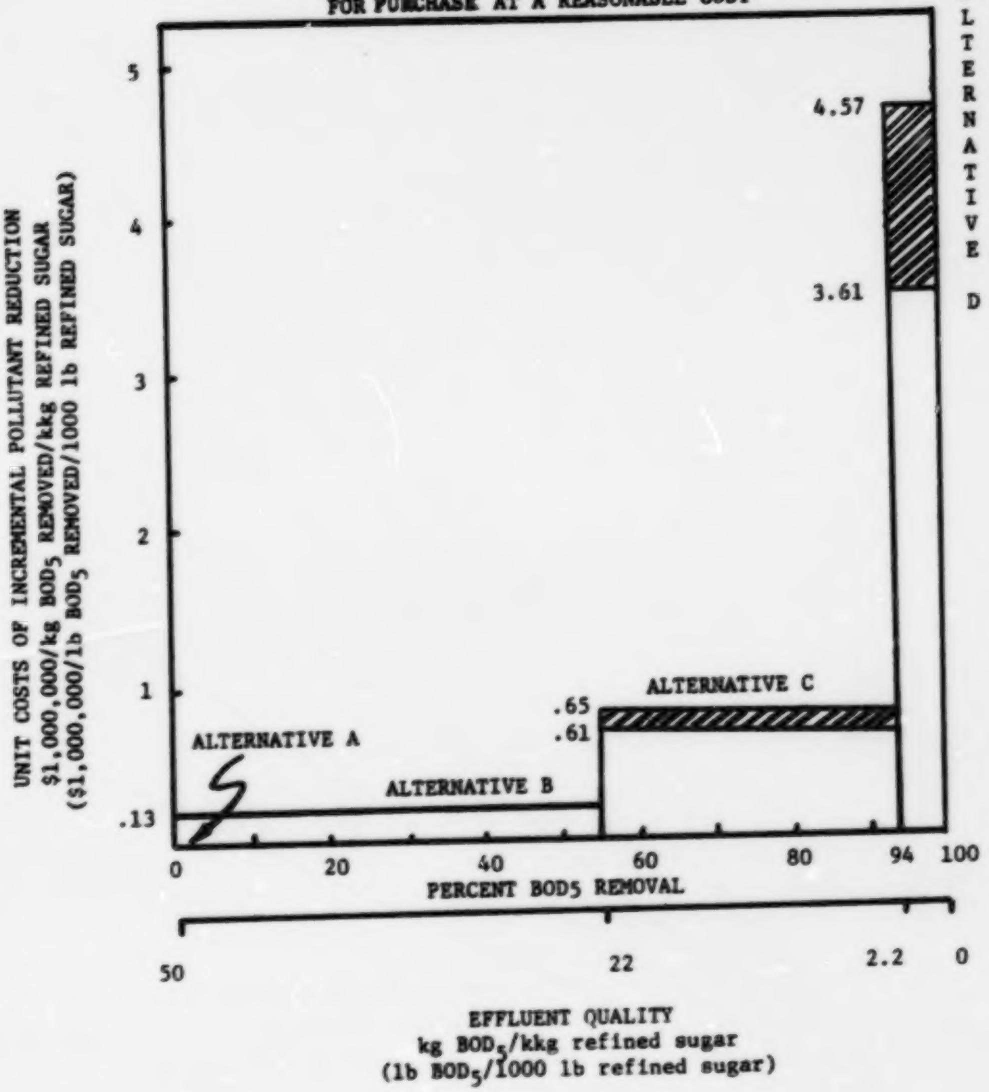
FIGURE XIII
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND
NOT PHYSICALLY AVAILABLE ADJACENT TO THE PLANT SITE
BUT LOCATED AT A REASONABLE DISTANCE UNDER PLANT OWNERSHIP



ASSUMPTIONS

1) LAND COST OF \$4938/ha (\$2000/ac) INCLUDING POND CONSTRUCTION AND FILTRATION CONTROL MEASURES
2) 4.8 km (3.0 mi) DISTANCE TO DISPOSAL SITE
3) RIGHT-OF-WAY COSTS OF \$12,346/ha (\$5000/ac)
4) 377,728 kg REFINED SUGAR/DAY-PLANT (832,000 lb/DAY-PLANT)
5) 100 DAY CAMPAIGN
6) 0.635 cm/DAY (¼ in/DAY) FILTRATION RATE

FIGURE XIV
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND NOT PHYSICALLY AVAILABLE ADJACENT TO THE PLANT SITE NOT UNDER PLANT OWNERSHIP BUT LOCATED AT A REASONABLE DISTANCE AND AVAILABLE FOR PURCHASE AT A REASONABLE COST

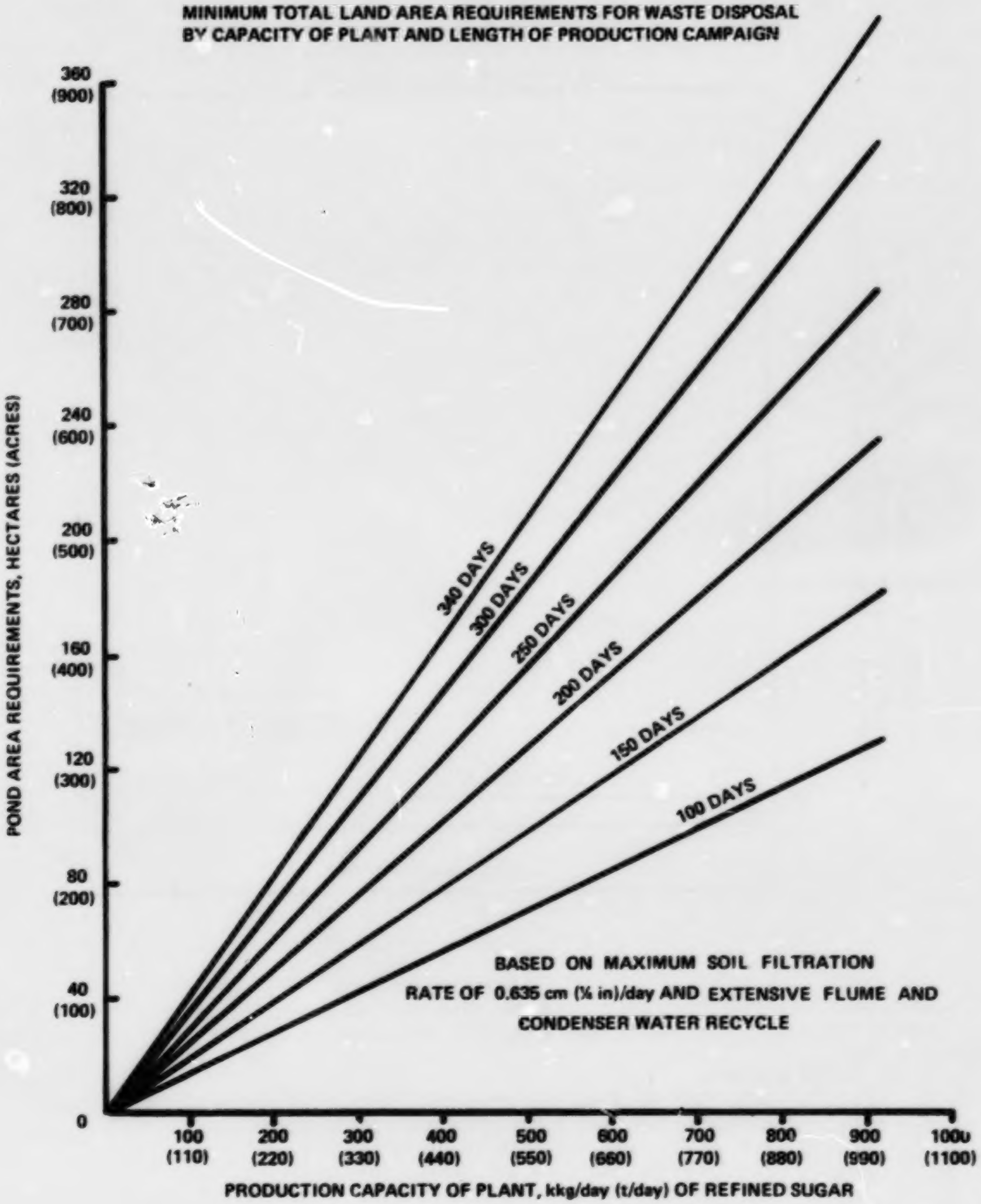


ASSUMPTIONS

1) LAND COST OF $7407/ha ($3000/ac) INCLUDING PURCHASE PRICE, POND CONSTRUCTION, AND FILTRATION CONTROL MEASURES
2) 4.8 km (3.0 mi) DISTANCE TO DISPOSAL SITE
3) RIGHT-OF-WAY COSTS OF $12,346/ha ($5000/ac)
4) 377,728 kg REFINED SUGAR/DAY-PLANT (832,000 lb/DAY-PLANT)
5) 100 DAY CAMPAIGN
6) 0.635 cm/DAY (¼ in/DAY) FILTRATION RATE

FIGURE XV

MINIMUM TOTAL LAND AREA REQUIREMENTS FOR WASTE DISPOSAL BY CAPACITY OF PLANT AND LENGTH OF PRODUCTION CAMPAIGN



processing for varying processing rates and campaign lengths are given by Figure XV.

Condition A serves as the basis for the cost estimates and pollutant reductions associated with zero discharge of waste waters to navigable waters. Further datails of this analysis are given above under Alternatives A through D for varying levels of pollution control for this condition. Other conditions described below (Conditions B, C, and D,) serve to delineate possible restraints of land availability and their resulting effects on the cost effectiveness of successful incremental pollutant removals under these land availability restraints.

Condition A - Necessary land for controlled waste water disposal is physically available adjacent to the plant site and under the ownership of the plant. Total land costs are assumed at $4940/ha ($2000/ac) which includes costs of holding pond construction and infiltration control measures.

Total capital costs = $454,000 to $676,000. Cost effectiveness curves are shown in Figure X and XI.

Condition B - Necessary land for controlled waste water disposal is physically available adjacent to the plant site but not under the ownership of the plant. Land costs are taken at $7410/ha ($3000/ac) including $2470/ha ($1000 per ac) purchase price and $4940/ha ($2000/ac) costs for pond construction and seepage control measures.

Total capital cost = $609,000 to $800,00 A cost-effectiveness curve for this condition is presented in Fig. XI.

Condition C - Necessary land for controlled waste water disposal is not physically available adjacent to the plant site, but suitable land is available under ownership of the plant within the plant vicinity. Suitable land for controlled waste water disposal is assumed to be available at 4.82 km (3 mi) from the plant site. Land costs are taken at $4940/ha ($2000/ac) including costs for pond construction and seepage control measures. Waste treatment costs are assumed to include all construction costs including pipeline, pumping station, engineering and design, right-of-way acquisition, and contingency costs. Costs of right-of-way are taken at $12,350/ha ($5000/ac) with 0.38 ha required/km (1.5 ac/mi) of pipe. A 3.7 m (12 ft) right-of-way is assumed.

Condition D - Necessary land for controlled waste water disposal is not physically available adjacent to the plant site. Suitable land for controlled waste disposal is located within 4.82 km (3 mi) of the plant site but not under ownership of the plant. Land costs are taken at $7410/ha ($3000/ac) including $2470/ha ($1000/ac) purchase price and $4940/ha ($2000/ac) costs for pond construction and seepage control measures. Waste transmission costs are assumed to include all contruction costs including pipeline, pumping station, engineering and design, right-of-way acquisition, and contingency costs. Costs of right-of-way are taken at $12,350/ha ($5000/ac) with 0.38 ha/km (1.5 ac /mi) of pipe. A 3.7 m (12 ft) right-of-way is assumed.

As expected, the cost relative to increased effectiveness in removal of pollutants (as measured by BOD_5) increases as the level of pollutant in the effluent decreases. This relationship is shown in Figure XI. As can be seen, in proceeding from Alternative C to Alternative D the increased capital costs per unit of pollution load reduced rises by a significant factor.

As developed in supportive material to this document,total industry capital costs with consideration of existing pollution control facilities and processes (Condition A) are estimated to range between approximately $9 million and $16 million for extensive recycling and reuse of flume (beet transport) and condenser water without discharge of process waste water pollutants to navigable waters. Corresponding total industry wide annual costs including operation and maintenance, depreciation, and annualization of capital expenditures are estimated at approximately $2.3 to $3.8 million for existing conditions. The above statement reflects the condition where suitable land for disposal of beet sugar processing waste is readily available and under plant ownership at the plant site. With land unavailability and the possible necessity for waste water piping to and purchase of suitable land, required industry-wide capital cost could reach as high as $16 to $20 million.

Basis of Assumptions Employed in Cost Estimation

Judgments and Assumptions Used

Annual interest rate for capital costs = 8% Salvage value of zero over 20 years for physical plant facilities and equipment Straight-line depreciation of capital assets Annual operating and maintenance expenses of 10 percent of capital costs for pollution control measures, permanent physical facilities, and equipment, except that an additional cost of $15,000 is allowed for solids removal from the flume water mud pond. The costs include all expenses attributed to operation and maintenance of control facilities, routine maintenance of equipment, labor, operating personnel, monitoring, and power costs.

Where adjustment of cost data to August 1971 dollars (the baseline of this report) was necessary, the cost figures have been adjusted in accord with indices published for use in EPA publication "Sewage Treatment Plant and Sewer Construction Cost Index," September, 1972. Cost-effectiveness relationships for the above alternative technologies are shown in Figures X and XIV. The basis for development of the curves is covered in detail in supportive material used in preparation of this document and the curves are included here for purposes of clarity of presentation.

Related Energy Requirement of Alternative Treatment and Control Technologies

Processing of sugar beets to refined sugar requires about 1.32 kw (1.61 hp) of electrical energy per kkg of beets sliced per day. This electrical energy demand is affected by factors such as: 1) The type of beet receiving and cleaning facilities, 2) whether or not a Steffen house is provided, 3) the lime production method, 4) the drying and pelletizing of beet pulp, and 5) the number of steam drive units compared to electrical motor drives, particularly in the higher power units.

The electrical energy consumption per unit of product output has continually increased over the years, and this trend appears unlikely to change in the foreseeable future. Among the primary reasons for increased demand are the extensive mechanization of the process, higher lighting illumination levels, and new practices e.g., waste water treatment, requiring additional electrical power for circulation pumps and aerators.

For a 3300 kkg (3600t) a day beet sugar processing plant, total energy requirements are estimated at 4320 kw (5800 horsepower) under operating conditions. Principal power requirements attributable to pollution control in a beet sugar processing plant are related to recirculation of waste water flows (primarily flume and condenser water) for in-plant reuse. Iverson reports the energy requirements, on the basis of experience with plants of the Great Western Sugar Company, to permit recycling of flume water flow. At a "typical" plant this is approximately 370 kw (500 horsepower). Because of the general similarity of waste volumes attributed to flume and condenser water, power requirements for recycling condenser water may logically be assumed to be the same as that for the recirculation of flume water. Thus, the total power requirement for recycling of both flume and condenser water is approximately 740 kw (1000 horsepower) or 20 percent of the total plant power requirement. Iverson also estimates that the additional annual power costs for pollution abatement purposes incorporating both the flume and condenser water recycling systems is estimated at approximately $22,000. The cost of energy is taken at 1 cent per kwh.

Because of its need for relatively large quantities of low pressure process steam, the beet sugar processing industry usually finds it economical to generate its own electric power. The power plant normally uses a non-condensing steam turbine generator which exhausts steam at the pressure required by the process. This power can be generated for about half the fuel required in a condensing steam turbine generator plant used for power generation only.

Regardless of the source of electrical power, steam-boiler facilities must be provided to supply the process steam requirements. With in-plant generation, the fuel chargeable to power is the additional fuel needed over that required for operation with purchased power. The cost of fuel chargeable to electric power generation by a non-condensing steam turbine is 0.425 mils per kwh for each 10 cents of fuel cost per 250,000 kg cal (1,000,000 Btu). Thus, using 40 cent fuel, and with a cost of purchased power of 8 mils/kwh with an assumed load of 4000 kw (5300 horsepower), the plant could pay for the entire installation cost of a non-condensing steam-turbine generating set in approximately 3 years, not including taxes.

The reliability of the main steam supply system and the need for process steam have made it normal practice to power the large horsepower individual loads with mechanically-driven, non-condensing steam turbines. Typical of such units are the carbon - dioxide and Steffen-refrigeration compressors. Turbine-driven compressors allow the steam designer further flexibility in balancing out the steam requirements in the whole plant.

Almost all beet sugar processing plants purchase some outside electrical power for standby when the plant is not in operation. Power is required for plant maintenance, liquid sugar production, bulk sugar handling, packaging operations, lighting, and office - machine operation. In the event of power plant disturbances and loss of plant generated power, the standby power provides for critical electrical loads such as emergency lighting and boiler plant and water systems. Usually it is not economical to size the utility company purchased power standby source to meet the total electrical demand of the plant. Generally, it is sized for about 20 percent of the total plant demand.

If properly designed, the electrical power system may be expanded readily with a minimum amount of additional investment (65).

Non-Water Quality Aspects of Alternative Treatment and Control Technologies

Air Pollution

There are three main items of air pollutional significance in the beet sugar processing industry: Suspended particulate matter, sulfur oxides, and odors. Fogging in the area of cooling towers or other cooling devices may present visibility problems in isolated cases.

Suspended Particulate Matter - The primary sources of potential particulate emissions result largely from the steam boiler and pulp drier stacks. Minor sources of particulate emissions include granulator exhaust, dry sugar, dried pulp, limestone, burnt lime and coal handling equipment, waste ponds, and kiln booster fans.

Properly designed and maintained gas- and oil-fired boilers should present no particulate emission problems. Fuel oil, however, can present a sulfur dioxide emission problem. One of the most economical methods to avoid sulfur dioxide emissions is to burn only low sulfur fuels.

Since some plants burn coal as a primary fuel, particulate emissions can be a problem. Fly ash, an emission common to all coal burning units, is composed of the ash and unburned combustibles which become airborne in the firebox and find their way to the atmosphere because of the velocity of the flue gas through the boiler and up the stack. The type of stoker equipment used has much to do with the amount of fly ash emitted. In terms of fly ash emission control, pulverized coal spreader stoker and chain grate and underfeed stoker units emit lesser amounts of fly ash to the atmosphere in that order respectively.

Fly ash emissions can usually be controlled with multicyclone mechanical collectors or electrostatic precipitators. A properly designed and installed mechanical collector will do a satisfactory job on virtually all types of coal-fired boilers except pulverized coal. Electrostatic precipitators are generally required on pulverized-fuel fired units. They have the advantage of increased efficiency with a low draft loss. Generally, the lower the sulfur content of the coal the poorer the efficiency of the precipitator. Precipitators are the most costly of the commonly used particulate collectors in boiler plants.

Smoke is unburned carbon and results from poor combustion. Smoke emissions are usually the most troublesome and visible at a beet sugar processing plant. Smoke emission problems from a boiler plant stem from many sources. Some of the main sources include the type of coal, load on the boiler, distribution of coal on the grate, overfire air, fuel to air ratio, fuel oil atomization, and grate and setting air seals. All of these problems may be alleviated through proper design, operation, and maintenance of the boiler facilities. These considerations are discussed in detail in Beet Sugar Technology, Second Edition (65).

The other major source of particulate material emanating from a beet sugar processing plant is that of the exhaust gases from the pulp dryer. These pollutants are pulp dust, molasses dust, fly-ash (if coal or oil fired), and smoke. Reduced emissions have been found to result by installing multiple cyclones of smaller diameter, or skimming a cyclone vent stack, thus removing much of the particulate matter load and returning the purified air to the furnace as dilution air for temperature control. A skimming system has two major advantages. First, a large portion of the particulate matter is removed from the exhaust; second, up to 10 percent increased thermal efficiency can be realized because of the smaller heating load on the dilution air, since the recycle gas is already above 93°C (200°F). The other source of air pollution in the pulp dryer is the dust created by the handling of dried pulp and pelleting equipment. This source can be controlled with a well-designed hood pickup system and a high efficiency mechanical collector.

Sulfur Dioxide - Boiler flue gas contains sulfur dioxide as an important air pollution source. Sulfur is present in all coals and most heavy fuel oils. Common gas scrubbing systems for removal of particulate material are generally rather ineffective in removal of sulfur dioxide. However, within the past year a Venturi-type scrubber has been installed at one beet sugar processing plant in the U. S. (Longmont, Colorado). It was installed at a cost of $500,000 and is reported to be quite effective in removal of sulfur dioxide as well as particulate solids. A similar installation is planned in the near future at Loveland, Colorado. The Venturi scrubber for boiler flue gas at the Longmont, Colorado, plant has an additional advantage as it utilizes barometric condenser water in the scrubbing process. This use results in reduction of condenser water volume through vaporization, which is a benefit where disposal of excess condenser water is a serious consideration. Barometric condenser water of 1900 to 2300 l/min (500 to 600 gal/min) is employed for the scrubbing process primarily for removal of fly ash.

The industry has generally found that change of the fuel source from coal to gas has been economically expedient in control of air pollution because of the large capital and operating expenditures required in scrubbing equipment needed for coal systems.

Odors - One of the most challenging problems of waste disposal at beet sugar processing plants is related to the matter of odor. When most of the plants were built, i.e., before 1930, they were located downstream from small towns. Inevitably, the towns have grown, often pressing close to the plant.

Odors of significance at beet sugar processing plants result largely from anaerobic bacterial action in waste water treatment systems, the pulp dryer, and beet piles where deterioration of the beets is occurring.

Ponding, particularly in deep anaerobic ponds, frequently promotes the growth of sulfur reducing organisms. It has been observed that careful screening of wastes to remove organic matter lessens or minimizes septic deposits of solids on the bottom of ponds, thereby reducing the quantity of noxious gases produced. Screening of waste water for removal of suspended organic material before discharge to holding ponds can substantially reduce the likelihood of noxious odor generation. The maintenance of shallow holding ponds and alkaline pH conditions aid in odor reduction and minimization. Purple sulfur bacteria (Chromatium and Thiopedia) have been found to be successful odor control mechanisms when cultured in waste stabilization lagoons utilized for beet sugar processing plant wastes at plants in California.

Fogging - A feature of cooling tower operation often overlooked is the generation of fog. This can create a hazard to highway traffic by impairment of visibility. A circle of influence of 0.8 km (0.5 mi) is usually regarded as a safe distance for avoidance of the effects of fog from these sources. Fogging due to water vapor in the vicinity of draft cooling towers can be expected to present problems with visibility at several existing plant locations. Such fogging practices would not be in the best environmental control practice or in some cases comply with local air pollution ordinances and state regulations. The potential problem is surmountable technologically by the use of closed, air-cooled heat exchanger cooling systems for these isolated instances. Such systems would incur an additional capital cost with reference to natural-draft or forced draft cooling towers and can technologically help to alleviate the problem. Air-cooled heat exchangers waste no water by evaporation, but they can cool only to within a few degrees of atmospheric temperature, and thus are limited to relatively high temperature applications. Combining systems to cool as far as possible with air and then to further accomplish temperature reduction in a conventional cooling tower or evaporative system of another type is often a more economical way of handling cooling loads. Elevation of the cooling tower to avoid or minimize visibility problems due to fogging is an alternative in many instances.

Solid Waste Disposal

The large volumes of dirt and solid material removed from sugar beets at the processing plant pose a perplexing problem for permanent disposal. Generally, about 50 kg of soil/kkg (100 lbs/ton) of beets sliced is contributed by a typical beet sugar processing plant. Where holding ponds are employed, solids accumulated in the ponds are removed annually and disposed of by adding the material to pond dikes. These ponds are generally abandoned after useful performance, with new holding pond facilities being established.

Sugar beets stored in large piles at the plant site or in outlying areas such as railroad sidings may be exposed to rodent activity and additional pollution from truck or railroad car unloadings. Rainfall may assist the spread of existing contamination.

In addition to the large volumes of soil delivered to the plant with the incoming beets, solid waste is also generated in terms of trash normally associated with municipal activities. Disposal of this material may be at the plant site or the waste material may be collected by the local municipality with disposal by incineration or sanitary landfill. The solid waste or trash consists of packaging materials, shipping crates, and similar dry combustible materials.

Sanitary landfills are generally best suited for non-combustible material and organic wastes which are not readily combustible such as decomposed beets, weeds, and peelings. Composting offers a viable alternative for disposing of organic materials such as decomposed beets, weeds, and peelings. Experience with this method in the disposal of municipal wastes has proved more costly than sanitary landfill operations, however. The sanitary landfill is probably the lower cost alternative, provided that adequate land is available.

Consideration of suitability is a prime factor in location of a landfill site. Requirements in selection of a landfill site include sufficient area, reasonable haulage distance, location relative to residential developments, soil conditions, rock formations, transportation access, and location of potential ground water polluting aquifers. Location of sanitary landfills in sandy loam soils is most desirable. Proper sloping of the landfill soil cover to promote runoff rather than ground percolation is necessary to prevent ground water pollution. Other factors to be considered include no obstruction of natural drainage channels, installation of protective dikes to prevent flooding when necessary, location of the base of the landfill operation above the high water table, and consideration of possible fire hazards. The general methods and desirable practices in operation of municipal sanitary landfill operations are equally applicable to disposal fo solid waste from beet sugar processing plants. Open burning of combustible wastes on the plant site is an undesirable and often unlawful method of solid waste disposal.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Introduction

The effluent limitations which must be achieved by July 1, 1977, are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category or subcategory. This average is not based upon a broad range of plants within the beet sugar processing subcategory, but rather on performance levels achieved by better plants. Consideration must also be given to:

a. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from the application;

b. the size and age of equipment and facilities involved;

c. the processes employed;

d. the engineering aspects of the application of various types of control techniques;

e. process changes;

f. non-water quality environmental impact (including energy requirements).

Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process, but also includes the control technology within the process itself when the latter is considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

Effluent Reduction Attainable Through the Application of Best Practicable Control Technology Currently Available

On the basis of the information contained in Sections III through VIII of this document a determination has been made that the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available for the beet sugar processing subcategory is as stated below.

The following limitations establish the quantity or quality of pollutants or pollutant properties controlled by this regulation which may be discharged by a point source subject to the provisions of this subpart after application of the best practicable control technology currently available; provided however, that a discharge by a point source may be made in accordance with the limitations set forth in either subparagraph (a) exclusively or subparagraph (b) exclusively below:

(a) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results from barometric condensing operations only.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD$_5$	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 32°C.	
(English units)	lb/1000 lb of product	
BOD$_5$	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 90°F.	

(b) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results, in whole or in part, from barometric condensing operations and any other beet sugar processing operation.

Effluent Characteristic	Effluent Limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD_5	3.3	2.2
TSS	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time.	
Temperature	Not to exceed 32°C.	
(English units)	lb/1000 lb of product	
BOD_5	3.3	2.2
TSS	3.3	2.2
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time.	
Temperature	Not to exceed 90°F.	

Identification of Best Practicable Control Technology Currently Available

Best Practicable Control Technology Currently Available for the beet sugar processing subcategory of the sugar processing point source category is extensive recycle and reuse of waste waters within the beet processing operation with no or controlled discharge of process waste water pollutants to navigable waters. To implement this level of technology requires:

a. Recycling of beet transport (flume) waters with partial or complete land disposal of excess waste water. This includes (1) screening; (2) suspended solids removal and control in the recirculating system; and (3) pH control for minimization of odors, bacterial populations, foaming, and corrosive effects.

b. Preferable recycling of barometric condenser water for condenser or other inplant uses with land disposal of excess condenser water.

c. Land disposal of lime mud slurry and/or reuse or recovery.

d. Return of pulp press water and other process waters to the diffuser.

e. Use of continuous diffusers.

f. Use of pulp driers.

g. Concentration of Steffen waste for disposal on dried beet pulp or byproduct utilization. Alternative methods such as land disposal may be considered.

h. Dry conveyance of beet pulp from diffusers to pulp driers.

i. Handling of all miscellaneous wastes; e.g., floor and equipment washes, filter cloth washes, etc., within the processing plant by subsequent treatment and reuse or land disposal.

j. Entrainment control devices must be installed on barometric condensers, and operation and control of the processes to minimize entrainment is necessary.

Rationale for Selection of Best Practicable Control Technology Currently Available

Basis for Units of Measurement in Effluent Limitations

The inherent variability in the sugar content of beets to be processed as influenced by climatic, soil and, cultural practices, and the application of effluent guidelines for condenser waters, particularly at those plants employing the "extended use" campaign, support the rationale for use of effluent limitations for condenser water based on unit production of refined sugar rather than based upon unit weight of beets sliced.

The sugar solutions after thickening in the "sugar end" of the process are relatively uniform in quality and predictable as to crystalline sugar yield. Condenser water quantities and characteristics are related to factors inherent in the processing of the relatively uniform sucrose - containing product. Sugar beets to be processed contain between 10 and 16 percent sugar. Sucrose content in sliced beets (cossettes) averaged 14.36 per cent in 1969 (Table II). Refined beet sugar production in the U. S. in 1969 was 115 kg per kkg (231 lbs. per ton) of beets sliced, with an averaged extraction rate of 80.43 percent.

Allowance for controlled discharge of composite waste in complying with the July 1, 1977, effluent limitations permits flexibility in reaching the established effluent limitations through use of alternative demonstrated control technologies without necessitating any change in the units of expression of the limitations.

Allowance for variability in biodegradable organic content of barometric condenser waters during processing of stored beets in later campaign in northern climates has been reflected in the maximum daily effluent limitation level.

Basis of Pollutant Limitations

The pollutants of general significance in beet sugar processing waste waters are BOD$_5$, total suspended solids, fecal coliforms, pH, and ammonia. For barometric condenser water alone, pollutants of significance are reduced to BOD$_5$, temperature, and pH.

BOD$_5$ (5-day, 20°C (68°F) Biochemical Oxygen Demand)

With proper attention to operation of evaporators and crystallizers in the sugar making process, vapor entrainment through the condensing process may be limited to between 30 and 50 mg/l BOD$_5$. Under reasonable control, BOD$_5$ loading in condenser water can be limited to 2.2 kg BOD$_5$/kkg (2.2 lb/1000 lbs) of refined sugar. This level of control corresponds with barometric condenser water use of 8300 l/kkg (2000 gal/ton) of beets sliced at a BOD$_5$ concentration of 30 mg/l as now practiced at many plants within the industry. Calculations based on the 0.5 lb BOD$_5$/ton of beets processed and the average production of 115 kg of refined sugar per kkg (231 lbs. per ton) of beets sliced, yields the established effluent limitation of 2.2 kg BOD$_5$/kkg (2.2 lb/1000 lb) of refined sugar produced. On this basis the discharge of BOD$_5$ during any period of 30 consecutive days shall not exceed 2.2 kg/kkg refined sugar. The discharge of BOD$_5$ during any one day period shall not exceed 3.3 kg/kkg refined sugar. This increased limitation for any one day discharge is justified on the basis of the occasional occurrence of process upsets and mechanical failures. Further reductions of BOD$_5$ in condenser waters are possible through reduction in cooling devices (15-50 percent) and through the use of elaborate entrainment control devices.

Temperature

The quantity of barometric condenser water utilized or required at an individual beet sugar processing plant varies with vapor condensing requirements, raw water source, process temperature considerations, and climatic factors. Condenser water leaving the barometric condenser process normally exhibits temperature characteristics at or near 65°C (149°F). Technology exists for cooling the condenser water before discharge to navigable waters. Cascading, reuse, water before discharge to navigable waters. Cascading, reuse, or recycling of the mildly contaminated condenser water can reduce the requirements and expense of facilities for cooling the total condenser water flow. In practice, cooling of heated waters is accomplished with spray ponds, cooling towers, and open ponds dependent on the cooling effect of evaporation. The terminal temperature to which heated water may be cooled may range from several degrees below atmospheric temperature at high humidity, to 17°C (30°F) or more below atmosperic temperature when the air is dry (88). Evaporative coolers are most effective and efficient in arid regions.

The temperature of water suitable for reuse in the barometric condenser water process is variable depending upon water use, reuse, conservation practices, and production-related factors. However, the normal temperature requirements for effective and efficient operation of the sugar solution concentrating and crystallizing processes are usually in the range of 20°C-25°C (68°F-77°F) or cooler. A maximum temperature limitation of 32°C (90°F) is technologically accomplishable and justified.

The same considerations of temperature apply to composite wastes and the 32°C (90°F) limitation should be equally applicable. Where composite discharge of process waste water occurs, 32°C (90°F) for composite waste discharge generally presents no difficulty to meet since temperature reduction can usually be technologically accomplished principally through a combination of waste waters from barometric condensing operations together with other wastes.

Ammonia

Ammonia in barometric condenser water varies between 3 and 15 mg/l NH_3 as nitrogen depending upon the condition of beets processed and the existence, non-existence, or effectiveness of entrainment control devices. Higher ammonia entrainment in condenser water is evident during the later stages of the processing campaign particularly in areas where storage of beets is practiced and progressive deterioriation of the beets results. Ammonia, like other dissolved gases, may be separated by heat or agitation and leave no residue on evaporation. Evaporative cooling devices for heated waste waters are effective in accomplishing essentially complete removal of ammonia through stripping. Because of this phenomenon, no specific numerical standard for ammonia nitrogen in barometric condenser discharge water is established. Similar ammonia concentrations occur in flume waters which are readily reduced through biological action.

pH

Barometric condenser water picks up ammonia from the evaporating juices, hence is always alkaline, ranging from pH 8 to 11, but usually less than 9. Reduction of ammonia concentrations will effectively control the pH within the designated limits. On this basis and in accord with accepted water quality standards the pH of the discharge must be maintained within the range of 6.0 to 9.0. High pH levels (above 8.0) often result in flume water recycling systems by the addition of lime to control odor and other factors.

Total Suspended Solids

This pollutant parameter has particular significance where treatment, handling, and disposal of flume water results which influences the solids level of a composite process waste water discharge to navigable waters. Total suspended solids levels in barometric condenser water are negligible and are subject to the same methods and procedures for control as BOD_5. Generally since both BOD_5 and TSS are derived from the process of concentration of sugar-laden solutions, control of BOD_5 will likewise result in control of corresponding TSS levels in barometric condenser water. The limitation for TSS corresponding to that for BOD_5 may be expeditiously accomplished as presently demonstrated within the industry for composite waste through effective solids removal devices.

Fecal Coliforms

A measure of fecal coliforms is an indirect measure of possible pathogenic bacteria which may be associated with the fecal coliform organisms. Fecal coliforms have been shown to be derived from and resulting from the application of animal manures to beet crops, and therefore, is an important criterion only where composite process waste water (including flume water) is discharged to navigable waters. Fecal coliform levels are subject to control through currently available and applied tehcnology. Evidence does not indicate the presence of fecal coliform organisms in barometric condenser waters to be of serious concern.

Total Cost of Application in Relation to Effluent Reduction Benefits

The cost effectiveness of attaining zero discharge of process waste waters to navigable waters for the beet sugar processing industry is given in Figures X through XIV for various identified conditions at the beet sugar processing plants where unfavorable soil, climate, land availability, and land costs exist. The cost effectiveness relationships bear particular significance in relation to the relative costs of achieving the elimination of barometric condenser water from navigable waters and the associated land availability requirements. Exception to the effluent guidelines limitation of no discharge of process waste water pollutants to navigable waters is justified on the basis of practical land availability considerations and economic factors to be imposed upon the beet sugar processing subcategory in achieving this limitation for affected plants by July 1, 1977.

BOD$_5$ reduction is accomplished through effective entrainment control devices in pan evaporators and crystallizers. An undetermined amount of BOD$_5$ reduction (probably 15 to 50 percent) occurs as a secondary benefit in the required cooling device. The amount of BOD$_5$ reduction attendant to cooling under the specified technology cannot be reliably predicted. The BOD$_5$ reduction effected would be dependent to a large extent on individual operating practices and type of facilities.

Age and Size of Equipment and Facilities

As set forth in this document, industry competition and general improvements in production methods have hastened modernization of plant facilities throughout the industry.

Age and size are not within themselves determining factors in the application of Best Practicable Control Technology Currently Available for the beet sugar processing subcategory of the sugar processing point source category. Estimated costs of pollution reduction tend to vary uniformly with plant size because of the land based waste disposal technology and variance of raw waste contribution directly with plant capacity. Age and size of plant are most appropriately related to general land availability--a factor receiving appropriate consideration in establishing practical effluent reduction levels attainable for this level of technology.

Processes Employed

All plants of the beet sugar processing subcategory manufacture refined sugar using the same or similar production methods, the discharges from which are also similar. There is no evidence that operation of any current process or subprocess will substantially affect capabilities to implement Best Practicable Control Technology Currently Available.

Engineering Aspects of Control Technique Applications

Land disposal of process waste waters is an integral part of the best practicable control technology currently available for the beet sugar processing subcategory as evidenced by present widespread use. Reduction of pollutants through biological processes commonly attendant with process waste water storage and/or aeration for odor control occurs but varies with local factors. A high degree of pollution control has been demonstrated to be capable of being achieved through a combination of use of land disposal, biological and chemical treatment, and waste water recycling and reuse.

The use of controlled land disposal of process waste waters is a widespread practice for many types of wastes including both municipal and industrial within and outside the United States. As noted in Table VIII, essentially all present beet sugar processing plants rely either in whole or in part on land for waste water disposal. Such disposal on land by filtration through holding ponds, or use after treatment for irrigation, is not generally accomplished under controlled filtration conditions and no significant problems of water quality from such waste water disposal have been identified or recognized.

Furthermore, disposal by land application of beet sugar processing waste waters has obvious benefits of cost-effectiveness and practical application as compared to utilization of conventional biological treatment measures. For reasons developed within the document such as the varying and seasonal nature of the waste and adaptability of conventional treatment measures to beet sugar processing, conventional biological treatment has generally proved to be unsuccessful in application to date.

Land disposal of food processing and other wastes is extensively practiced in many areas of the country without ill effects. A fully developed water technology should make maximum practicable use of ground water recharge.

The concepts are proved, and available for implementation. Required production and waste management methods may be readily employed through adaptation or modification of existing production units.

Process Changes

In-process technology is an integral part of the waste management program now being implemented within the industry. Some degree of in-process control is now practiced by all plants within the subcategory.

Climatic Factors

Climatic factors of precipitation and evaporation vary substantially throughout the regions in which beet sugar processing plants are situated in the United States. Examination of evaporation and rainfall records in these locations reveals that the most critical region for disposal of waste water by evaporation is the Ohio-Michigan area where annual rainfall and lake evaporation is the Ohio-Michigan area where annual rainfall and lake evaporationb approximately compensate one another. All other areas of the country in which beet sugar processing plants are located experience a net evaporation rate.

The mechanism for controlled process waste water disposal through land application adapted for purposes of this document relies solely upon land disposal by controlled soil filtration. Reliance upon controlled soil filtration would in all cases except in the Michigan-Ohio area provide for increased benefits for reduction in land requirements due to actual net evaporation which occurs. Therefore, reliance upon controlled seepage for waste water disposal effectively eliminates or minimizes the effects of climatic factors on the established pollution control technology. Effects of land requirements and soil filtration rates have been appropriately discussed under the heading of land availability above.

Climatic conditions together with varying soil conditions, harvesting Climatic conditions together with varying soil conditions, harvesting procedures, and geographic factors may affect soil loads on incoming beets and the condition of beets as received for processing at the processing plant. Increased soil loads on incoming beets result in increased mud handling costs and expense of disposal. These increased handling costs are assumed by the plant in accepting sugar beets from growers and are a relatively insignificant expense relative to total production costs. Increased soil loads may result in the need for more frequent cleaning of flume water settling and holding ponds.

Non-Water Quality Environmental Impact

There are two essential impacts upon major non-water elements of the environment: A limited degree of direct effects upon ambient air quality (e.g., fly ash from pulp driers, odors); and a potential effect on soil systems due to strong reliance upon the land for ultimate disposition of final effluents. In the former case, responsible operation and maintenance procedures have been shown to minimize the problems. Moreover, the vast enhancement to water quality management provided by using the suggested pollution control processes substantially outweigh these reasonably controllable air effects.

With respect to the concern of subsurface pollution, it is addressed only in a precautionary context since no evidence has been discovered which indicates a strong or direct impact. All evidence points to the contrary. Technology and knowledge are available to assure controlled land disposal or irrigation systems with land application of process waste water commensurate with crop need or soil tolerance.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

Introduction

The effluent reduction attainable through the application of the Best Available Technology Economically Achievable is given below. In determining this level of technology high reliance has been made on available technology applicable for pollution control for the subcategory with associated expected economic impact effects.

Effluent Reduction Attainable Through the Application of Best Available Technology Economically Achievable

On the basis of the information contained in Sections III through VIII of this document a determination has been made that the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable for the beet sugar processing subcategory is as stated below.

The following limitations establish the quantity or quality of pollutants or pollutant properties controlled by this regulation which may be discharged by a point source subject to the provisions of this subpart after application of the best available technology economically achievable.

(a) The following limitations establish the quantity or quality of pollutants or pollutant properties which may be discharged by a point source where the sugar beet processing capacity of the point source does not exceed 2090 kkg (2300 tons) per day of beets sliced and/or soil filtration rate in the vicinity of the point source is less than or equal to 0.159 cm (1/16 in) per day; provided however that a discharge by a point source may be made in accordance with the limitations set forth in either subparagraph (1) exclusively or subparagraph (2) exclusively below:

(1) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results from barometric condensing operations only.

Effluent Characteristic	Effluent Limitations Maximum for any one day	 Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD_5	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 32°C.	
(English units)	lb/1000 lb of product	
BOD_5	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Temperature	Temperature not to exceed the temperature of cooled water acceptable for return to the heat producing process and in no event greater than 90°F.	

(2) The following limitations establish the maximum permissible discharge of process waste water pollutants when the process waste water discharge results, in whole or in part, from barometric condensing operations and any other beet sugar processing operation.

Effluent Characteristic	Effluent Limitations Maximum for any one day	 Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/kkg of product	
BOD_5	2.0	1.3
TSS	2.0	1.3
pH	Within the range of 6.0 to 9.0.	
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time.	
Temperature	Not to exceed 32°C.	
(English units)	lb/1000 lb of product	
BOD_5	2.0	1.3
TSS	2.0	1.3

pH	Within the range of 6.0 to 9.0.
Fecal Coliform	Not to exceed MPN of 400/100 ml at any one time (not typically expressed in English units).
Temperature	Not to exceed 90°F.

(b) The following limitations establish the quantity or quality of pollutants or pollutant properties controlled by this regulation which may be discharged by a point source in all instances not specified under the provisions of a) above: There shall be no discharge of process waste water pollutants to navigable waters.

Identification of Best Available Technology Economically Achievable

Best Available Technology Economically Achievable for the beet sugar processing subcategory of the sugar processing point source category is as developed in Section IX with inclusion of higher levels of organic entrainment control in barometric condenser waters and/or increased treatment and/or control of waste water by biological, physical, and chemical treatment and land application of waste waters. The practices identified under Section IX are equally applicable to this level of technology. The technology may be met by a wide variation of waste handling, treatment, and disposal methods.

Rationale for Selection of Best Available Technology Economically Achievable

The industry has amply demonstrated that no discharge of process waste water pollutants can be achieved where suitable and available land for disposal of process waste waters exists. The recommended guidelines provide an extended time period for obtaining the recommended land resources with which to meet the requirement of no discharge of process waste water pollutants to navigable waters.

There are presently 11 of 52 beet sugar processing plants in the United States accomplishing no discharge of process waste water pollutants to navigable waters. This level of technology is generally being accomplished through extensive recycling and/or reuse of process waste water with disposal of excess waste waters by soil filtration or for crop irrigation after biological treatment with waste holding. No discharge of waste waters to surface waters occurs from these waste disposal and treatment operations. The plants accomplishing no discharge of process waste water pollutants to navigable waters are identified in Table VIII. Even though these plants are generally in water short areas, where factors are relatively favorable for land disposal, such a technology can be technically accomplished at all beet sugar processing plants if the necessary land is available and suitable.

Even though land disposal is generally an integral part of pollution abatement measures for control of beet sugar processing waste, many factors influence the use, availability, and suitability of land for waste disposal. Segmentation of the subcategory as stipulated recognizes the need for consideration of plant size and soil filtration rate as principally affected economic factors. The following factors are presented in support of the limitations as developed:

1. No plants anticipated to experience soil filtration rates of 0.159 cm (1/16 in) per day or less are currently achieving no discharge of process waste water pollutants to navigable waters.

2. All those plants anticipated to experience a soil filtration rate of 0.159 cm (1/16 in) per day or less are identified in the economic impact analysis to experience the greatest probable economic impact resulting from pollution control regulations.

3. No plants having a sugar beet processing capacity of 2090 kkg (2300 tons) per day of beets sliced or less presently accomplish no discharge of process waste water pollutants to navigable waters. Of the 16 plants below the size designation, 3 presently discharge excess process waste water to municipal systems and would experience some economic impact restraints if they were required to provide needed biological treatment and/or land for waste disposal. Three of these plants are on the baseline closure list; i.e., would likely incur adverse economic impact irregardless of pollution control requirements. The economic analysis indicates 5 plants would be classified on the high probability of closure list with consideration of pollution control requirements. Five plants are also identified as likely to experience medium probability of adverse economic impact as a result of pollution control requirements. The plant size selected as a basis for segmentation constitutes a logical break in the industry for purposes of economic impact factors.

4. Five plants located in Michigan would find it extremely difficult to meet a requirement of no discharge of process waste water pollutants to navigable waters. Their land requirements would be excessive due to poor evaporation and low soil filtration rates (less than 1/16 in. a day). Even if land were available, the costs may be beyond their economic capabilities. Municipal systems may become subsequently available, but there is no certainty that this will occur. A similar situation exists for approximately 4 plants in Minnesota and North Dakota although the problems for these plants do not appear as critical.

5. From 2 to 8 plants in Colorado, Nebraska, and Wyoming are expected to have difficulties with a requirement of no

discharge of process waste water pollutants due to economic reasons. They are all relatively old and small and tend to be located in areas of high land cost.

Land disposal of waste waters without discharge to surface waters would result in a possible net loss of water from surface streams from the most extensive waste water recirculation system of a straighthouse beet sugar processing plant of 3200 l/kkg (781 gal/ton) of beets sliced. The total water loss of this tonnage volume would consists of 825 l/kkg (203 gal/ton) of beets sliced loss to the atmosphere through process venting and evaporation, moisture in screenings, and molasses production; and 2440 l/kkg (578 gal/ton) of beets sliced loss due to land disposal of required blowdown from flume and condenser water recycling systems.

In consideration of water gains and losses in an average-sized 3300 kkg (3600 ton) of beets sliced per day beet sugar processing plant, possible net loss of water to a stream would be estimated at about 10.5 million liters (2.8 million gal) per day assuming the complete source of fresh water is a surface water source. However, because of cooling considerations wide use of cooler ground water supplies as the source of fresh water requirements to the beet sugar processing plant is made. With use of surface waters as the sole source of water supply, approximately 8.0 million liters (2.1 million gal) per day may be disposed of and/or added to ground water supplies through land application without discharging process waste water pollutants to surface waters. Where crop irrigation is practiced, uptake of water by plants offers a consumptive but beneficial use of the waste water. In addition to fresh water, incoming beets constitute a major source of water addition of 800 l/kkg (192 gal/ton) of beets sliced to the extensive recycling system.

A detailed discussion of water gains and losses is included under the heading of Mass Water Balance in a Beet Sugar Processing Plant, Section VII of this document.

The above estimates give due consideration for water gain attributable to moisture within incoming beets and water losses resulting from various sources. Total water supply from surface water sources is assumed which results in many cases in an overestimation of consumptive use from surface waters for plant processes and pollution control. In fact, many plants utilize ground water sources of water supply rather than surface waters, and waste water returned to the ground through land disposal usually may be reclaimed as ground water supply or eventually finds its way, generally in a purified state, back to surface waters.

The basis for limitation of various pollutants is as developed in Section IX with consideration of improved practices and operations which may result in the reduced effluent limitations levels as presently demonstrated within the beet sugar processing subcategory.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

The standard of performance for new sources representing the degree of effluent reduction attainable through the application of the best available demonstrated control technology has been determined to be no discharge of process waste water pollutants to navigable waters. An allowance for a variation of the standard is not needed since land availability requirements should be considered in site selection for a new point source.

Introduction

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." This level of technology shall be evaluated by adding to the consideration underlying the identification of Best Available Technology Economically Achievable a determination of what higher levels of pollution control are available through the use of improved production processes and and/or treatment techniques.

Effluent Reduction, Identification and Rationale for Selection of New Source Performance Standards

The effluent limitation is for new sources no discharge of process waste water pollutants to navigable waters as developed in Section X.

SECTION XII

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C. R. McSwiney	Effluent Guidelines Division
Richard V. Watkins	Project Officer, Effluent Guidelines Division
George Webster	Effluent Guidelines Division
Kit Krickenberger	Effluent Guidelines Division
Swep Davis	Office of Planning and Evaluation
George Keeler	Office of Research and Monitoring

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Ken A. Dostal	Office of Research and Monitoring Corvallis, Oregon
Harold W. Thompson	Office of Research and Monitoring Corvallis, Oregon
Ed Brooks	Office of Toxic Substances
Ed Struzeski, Jr.	National Field Investigation Center Denver, Colorado
Kit Smith	Office of General Council
Erik Krabbe	Region II
M. Shamaiengar	Region V
R. L. Markey	Region VII
Melvin McCorkle	Region VII
Bob Burm	Region VIII
Irwin Dickstein	Region VIII
Robert D. Shankland	Region VIII

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SECTION XIII

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SECTION XIV

GLOSSARY

Activated Sludge Process

A biological sewage treatment process in which a mixture of sewage and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated sewage (mixed liquor) by sedimentation and wasted or returned to the process as needed. The treated sewage overflows the weir of the settling tank in which separation from the sludge takes place.

Aeration

The bringing about of intimate contact between air and a liquid by one of the following methods: Spraying the liquid in the air; bubbling air through the liquid or agitation of the liquid to promote surface absorption of air.

Aeration Period

(1) The theoretical time, usually expressed in hours, that the mixed liquor is subjected to aeration in an aeration tank undergoing activated sludge treatment; equal to (a) the volume of the tank divided by (b) the volumetric rate of flow of the sewage and return sludge. (2) The theoretical time that water is subjected to aeration.

Air Pollution

The presence in the atmosphere of one or more air contaminants in quantities, of characteristics, and of a duration, injurious to human, plant, or animal life or property, or which unreasonably interferes with the comfortable enjoyment thereof.

Alkalinity

A quality of waste waters due to the presence of weak bases composed primarily of bicarbonates, carbonates, and hydroxides.

Ammonia Nitrogen

All nitrogen in waste waters existing as the ammonium ion.

Anaerobic

Living or active in the absence of free oxygen.

Ash

The solid residue left after incineration in the presence of oxygen. In analysis of sugar products, sulfuric acid is added to the sample, and this residue as "sulfated ash" heated to 800°C is taken to be a measure of the inorganic constituents. It is sometimes determined indirectly by measure of the electrical conductivity of solutions of the products.

Bacterial Quantity Unit (BQU)

One measure of the total load of bacteria passing a given stream location and is particularly useful in comparing relative loads between stations. The number of BQU's is derived as the product of flow in cfs and coliform density in MPN per 100 ml, divided by 100,000.

Beet End

The part of the sugar plant which includes the process through the evaporators. In plants where the vacuum pans are heated by vapors the evaporators are usually included in the sugar end.

Beet Pulp

The vegetable matter left after sugar is extracted from cossettes. Used, wet, dehydrated, or pelleted as commercial cattle feed.

Biological Filtration

The process of passing a liquid through a biological filter containing media on the surfaces of which zoogleal films develop which absorb fine suspended, colloidal, and dissolved solids, and release end products of biochemical action.

Biological Process

The process by which the life activities of bacteria and other microorganisms in the search for food break down complex organic materials into simple, more stable substances. Self-purification of sewage polluted streams, sludge digestion, and all so-called secondary sewage treatments result from this process.

Beet Wheel

A large wheel with baffles projecting radially inward from the surface of the perforated rim and used to raise beets to a higher plane and separate them from the flume water; e.g., as from a flume to a beet washer.

BOD5 - 5-day, 20°C Biochemical Oxygen Demand

The quantity of oxygen used in the biochemical oxidation of organic matter over a five-day period of incubation at 20°C. The procedure is a standard test used in accessing waste water pollutional strength. (The term is printed as BOD5 rather than using the subscript number because of printing limitations.)

Blowdown

A discharge from a system designed to prevent a buildup of some material, as in a boiler to control dissolved solids.

Brix

A hydrometer scale calibrated to read percent sugar by weight in pure sugar solutions. Originated by Balling, improved and corrected by Brix.

Calcination

The roasting or burning of any substance to bring about physical or chemical changes; e.g., the conversion of lime rock to quicklime.

Campaign

The period of the year during which the beet sugar processing plant produces sugar.

Carbonation

The process of treatment with carbon dioxide gas.

Caustic

Capable of destroying or eating away by chemical action. Applied to strong bases.

Chain-grate Stoker

A stoker system which moves the coal in a continuous bed from the bottom of a feed hopper into the furnace by means of a moving grate, consisting of a continuous belt constructed of many individual cast - iron chain links so assembled as to allow air to pass through.

Clarification

The process of removing undissolved materials from a liquid. Specifically, removal of suspended solids either by settling or filtration.

Coagulation

(1) The agglomeration of colloidal or finely divided suspended matter by the addition to the liquid of an appropriate chemical coagulant, by biological processes, or by other means. (2) The process of adding a coagulant and necessary other reacting chemicals.

COD - Chemical Oxygen Demand

A measure of the oxygen consuming capacity of inorganic and organic matter present in water or waste water. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test.

Conductivity

A measure of the ability of water in conducting an electrical current. In practical terms, it is used for approximating the salinity or total dissolved solids content of water.

Cossette

Long, thin strips into which sugar beets are sliced before sugar-containing juices are extracted. The strips somewhat resemble shoestring potatoes.

Crop Year

In the sugar beet area in Southern California and all other States the crop year corresponds to the calendar year of planting. In Northern California, a crop of sugar beets planted in the interval beginning November 1 of one calendar year through October 31 of the following calendar year is designated by crop year to correspond with that following calendar year.

Depletion or Loss

The volume of water which is evaporated, embodied in product, or otherwise disposed of in such a way that it is no longer available for reuse in the plant or available for reuse by another outside the plant.

Diffuser

An apparatus into which water and cossettes are fed, the water extracting sugar from the sugar beet cells.

Detention Period

The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

DO - Dissolved Oxygen

The oxygen dissolved in waste water or other liquid expressed in mg/l or percent of saturation.

Dust Box

A device to remove sugar dust from air, usually employing water sprays; a dust collector.

Effluent

Process waste water, treated or untreated, resulting from beet sugar processing operations.

Earthen Pond

A pond constructed with or without filtration control measures for the purpose of detention, long-term storage, or land disposal of influent waste waters.

Electrostatic Precipitator

A gas cleaning device using the principle of placing an electrical charge on a solid particle which is then attracted to an oppositely-charged collector plate. The device uses a d-c potential approaching 40,000 volts to ionize and collect the particulate matter. The collector plates are intermittently rapped to discharge the collected dust into a hopper below.

Extraction Rate Efficiency

The percentage relationship between the sugar recovered and the sugar content in sugar beets.

Faculative Pond

An earthen detention facility for treatment of process waste water incorporating both aerobic and anaerobic biological regimes.

Fecal Coliform Bacteria

A group of bacteria of fecal origin within the coliform group inhabiting the intestines of man or animal. The group comprises all of the aerobic and facultative anaerobic, gram negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. In addition, the bacteria will produce gas within 24 plus or minus 3 hours at 43 plus or minus 0.2°C when inoculated into EC culture medium.

Filtrate

Liquid after passing through a filter.

Filtration

Removal of solid particles from liquid or particles from air or gas stream by passing the liquid or gas stream through a filter medium.

Flume Waste Water

The normal term applied to the discharge of flume water which is employed to convey beets into the beet sugar processing plant.

Gas Washer

Apparatus used to remove entrained solids and other substances from carbon dioxide gas from a lime kiln.

Glucose

(1) An alternate chemical name for dextrose. (2) A name given to corn syrup which is obtained by the action of acids and/or enzymes on cornstarch. Commercial corn syrups are nearly colorless and very viscous. They consist principally of dextrose and another sugar, maltose, combined with gummy organic materials known as dextrins, in water solution.

Granulator

A rotary drier used to remove free moisture from sugar crystals before packaging or storing.

Ground Water

Water in the ground beneath the surface. In a strict sense the term applies only to water below the water table.

Holding Pond

An earthen facility, with or without lining to control soil filtration, constructed for the primary purpose of waste detention before discharge, or containment or disposal of waste water without direct discharge to surface waters by the mechanisms of evaporation and ground filtration. Within the context of the meaning of the term filtration used in this report, filtration shall imply controlled ground filtration within specified limitations, and such as not to contribute adversely to the quality of ground or surface waters. Filtration control measures may be required to limit filtration from holding ponds within this context.

Lime Cake

The lime mud resulting upon clarification and purification of the raw sugar juice by heating, lime addition, and precipitation in an insoluble precipitate.

Lime Mud Slurry

The product resulting from the addition of water to lime cake to facilitate pumping of the material for further handling and/or disposal.

Lime Pond

An earthen diked area to which the lime mud slurry or waste filter cake is transported and held.

Massecuite

The mixture of mother liquor and sugar crystals produced in the sugar boiling process (literally, a "cooked mass").

Mechanical Clarifier

A man-made device designed specifically for the detention of waste water for the purpose of removal of the settleable solids from the waste water under controlled operating conditions.

Molasses

A dark-colored syrup containing non-sugars produced in processing both beet and cane sugar. Beet molasses is used as commercial cattle feed or in the manufacture of monosodium glutamate, a food flavoring agent, alcohol, yeast, citric acid, and other products.

Mother Liquor

The solution from which crystals are formed.

MPN - Most Probable Number

In the testing of bacterial density by the dilution method that number of organisms per unit volume which, in acccordance with statistical theory, would be more likely than any other possible number to yield the observed test result or which would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml.

Nitrification

The oxidation of organic nitrogen into nitrates through biochemical action.

Nonsugar

Any material present, aside from water, which is not a sugar.

Pan

A single-effect evaporator used to crystallize sugar.

Percentage Reduction

The ratio of material removed from water or sewage by treatment to the material originally present (expressed as a percentage).

pH

A measure of the relative acidity or alkalinity of water. The reciprocal of the logarithm of the hydrogen ion concentration. A pH value of 7.0 indicates a neutral condition, less than 7.0 indicates a predominance of acids, and greater than 7, a predominance of alkalis.

Process Effluent or Discharge

The volume of water emerging from a particular use in the plant.

Pond Lime

Lime cake after being run into waste ponds.

Population Equivalents (P.E.)

Description of the pollutional effect of various waste discharges in terms of a corresponding effect of discharging raw sewage from an equivalent number of human population. Each P.E. represents the waste contributed by one person in a single day, generally equivalent to 0.17 lbs BOD_5.

Process Waste Water

All water used in or resulting from the processing of sugar beets to refined sugar, including barometric condenser water, beet transport (flume) water, and all other liquid wastes including cooling waters.

Pulp Press

A mechanical pressure device which squeezes the exhausted cossettes (pulp) to remove a portion of the inherent water.

Pulp Screen Water

Water which is drained from the wet insoluble pulp after the diffusion process but before the pulp is pressed to remove extraneous water and sugar.

Pulp Silo Drainage

Drainage water resulting from discharge of pulp from the diffuser with screenings to a silo equipped with channels for drainage water collection.

Purity

A measure of the actual sugar content in relation to the total dry substance in sugar beets. Specifically, the percentage of sucrose in total solids.

Raw Sugar

Raw Sugar is an intermediate product consisting of crystals of high purity covered with a film of low quality syrup.

Raw Value

Raw value is a computed weight of sugar used in the Sugar Act for a common expression of different types and qualities of sugar. The major types of sugars are converted to raw value as follows:

(1) For hard refined crystalline sugar multiply the number of lb thereof by 1.07.
(2) For raw cane sugar, multiply the number of lb by the figure obtained by adding to 0.93 the result of multiplying 0.175 by the number of degrees and fractions of a degree of polarization above 92 degrees.
(3) For sugar and liquid sugar, testing less than 92 degrees by the polariscope, divide the number of lb of the "total sugar content" thereof by 0.972.

Raw Sugar Juice

The liquid product remaining after extraction of sugar from the sliced beets (cossettes) during the diffusion process.

Riparian

An adjective describing anything connected with or adjacent to the banks of a stream or other body of water.

Refined Sugar

A high purity sugar normally used for human consumption.

Saccharate Milk

A slurry of calcium saccharate from the Steffen process.

Screening

The removal of relatively coarse floating and suspended solids by straining through racks or screens.

Seal Tank

The tank on the bottom of a barometric leg pipe.

Sedimentation

The sedimentation of suspended matter in a liquid aided or unaided by chemicals or other special means and without provision for the decomposition of deposited solids in contact with the sewage.

Slicer

Usually a drum on which V-shaped corrugated knives are mounted. This machine produces the cossettes.

Slicing Capacity

Processing capacity. The weight of sliced sugar beets a plant processes within a 24-hour period.

Sludge

The settled mud from a thickener clarifier. Also, in the Steffen process, the vacuum filter tray bottoms returned to the process as wet lime for preliming the diluted molasses. Generally, almost any flocculated, settled mass.

Steffen Process

A process employed at some beet sugar processing plants for recovery of additional sucrose from molasses. The process is generally carried on in conjunction with the main sugar extraction process at non-Steffen or "straight-house" plants. The process consists of the addition of finely ground calcium oxide to dilute molasses under low temperature conditions. Sugar, Steffen filtrate, and insoluble calcium saccharate are produced, filtered out, and generally reused at the main purification step of the normal "straighthouse" extraction process.

Steffen Filtrate

The waste which is separated from the calcium saccharate.

Sucrose

A disaccharide having the formula $C_{12}H_{22}O_{11}$. The terms sucrose and sugar are generally interchangeable, and the common sugar of commerce is sucrose in varying degrees of purity. Refined cane and beet sugars are essentially 100 percent sucrose.

Sugar

A sweet, crystallizable substance, colorless or white when pure, occurring in many plant juices and forming an important article of human food. The chief sources of sugar are the sugar cane and the sugar beet, the completely refined products of which are identical and form the granulated sugar of commerce. Chemically, sugar is a disaccharide with the formula $C_{12}H_{22}O_{11}$ formed by union of one molecule of dextrose with one molecule of levulose.

Supernatant

The layer floating above the surface of a layer of solids.

Spray Irrigation

Irrigation by means of nozzles along a pipe on the ground or from perforated overhead pipes.

Surface Irrigation

The process of waste water irrigation in which waste water is applied to and distributed over the surface of the ground.

Suspended Solids

(1) The quantity of material deposited when a quantity of waste water, sewage, or other liquid is filtered through an asbestos mat in a Gooch crucible. (2) Solids that either float on the surface of or are in suspension in water, sewage, or other liquids and which are largely removable by laboratory filtering.

Sweetwater

Dilute sugar solution, formed from washing filter cakes or granular carbon beds, too dilute to continue with the filtrate into the main process stream. Normally used in making milk of lime and saccharate milk.

Tare

Waste material which must be discharged. Also, the empty weight of a container used for weighing or transporting material.

Total Coliform Bacteria

Represents a diverse group of microorganisms whose presence has been classically used as indication of sewage pollution in water supplies. They are always present in the intestinal tract of man and other warm-blooded animals and are excreted in large number in fecal wastes. Where such fecal pollution exists there is always the possibility of the presence of enteric pathogenic bacteria and other pathogenic entities. Increasing density of the coliform bacteria group is assumed to represent an increase in the quantity of pollution and therefore greater hazard. It must be noted under some circumstances total coliform may be present which are derived from sources other than fecal excreta.

TDS - Total Dissolved Solids

The solids in water, sewage, or other liquids, which include the suspended solids (largely removable by filter paper) and the filterable solids (those which pass through filter paper).

Trickling Filter

A filter consisting of an artificial bed of coarse material, such as broken slag, clinkers, slate, slats, or brush, over which sewage is distributed and applied in drops, films, or spray, from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the applied sewage.

Vacuum Filter

A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth, revolving with a partial submergence in liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract moisture. The cake is scraped off continuously.

Vapor

Derived from boiling juices, as differentiated from steam generated in the boiler house or obtained from exhaust of turbines or engines.

Wet Scrubbing

A gas cleaning system using water or some suitable liquid to entrap particulate matter, fumes, and absorbable gases. The collected substances are then withdrawn along with the scrubbing liquid.

Waste Discharged

The amount (usually expressed by weight) of some residual substance which is suspended or dissolved in the plant effluent after treatment, if any, and conveyed directly to surface waters.

Waste Generated

The amount (usually expressed as weight) of some residual substance generated by a plant process or the plant as a whole and which is suspended or dissolved in water. This quantity is measured before treatment.

Watercourse

A channel in which a flow of water occurs, either continuously or intermittently and if the latter, with some degree of regularity. The flow must be in a definite direction. Watercourses may be either natural or artificial, and the former may occur either on the surface or underground. A different set of legal principles may apply to rights to use water from different classes of watercourses.

Water Rights

The rights acquired under the law to use the water occurring in surface or ground waters for a specified purpose and in a in surface or ground waters for a specified purpose and in a given manner and usually within the limits of a given period. While these rights may include the use of a body of water for navigation, fishing, and hunting, other recreational purposes, etc., the term is usually applied to the right to divert or store water for some beneficial purpose or use, such as irrigation, generation of hydroelectric power, or domestic or municipal water supply. In some states, a water right by law becomes appurtenant to the particular tract of land to which the water is applied.

Water Recirculation or Recycling

The volume of water already used for some purpose in the plant which is returned with or without treatment to be used again in the same or another process.

Water Use or Gross Use

The total volume of water applied to various uses in the plant. It is the sum of water recirculation and water withdrawal.

Water Withdrawal or Intake

The volume of fresh water removed from a surface or underground water source (stream, lake, or aquifer) by plant facilities or obtained from some source external to the plant.

Zooglea

A jelly-like matrix developed by bacteria. The word is usually associated with activated sludge growths in biological beds.

TABLE XVIII

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555(°F-32)[1]	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)[1]	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

[1] Actual conversion, not a multiplier

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